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THE FLOUR BEETLES OF THE GENUS TRIBOLIUM
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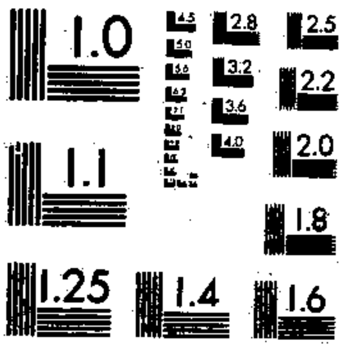

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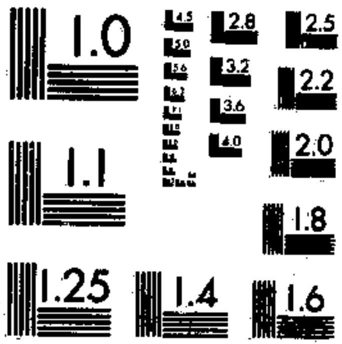

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THE FLOUR BEETLES OF THE GENUS TRIBOLIUM

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INTRODUCTION

Flour and other prepared products frequently become infested with small, reddish-brown beetles known as flour beetles. These beetles, although very similar in size and appearance, belong to the different though related genera *Tribolium*, *Gnathocerus*, *Palorus*, and *Latheticus*, of the family Tenebrionidae. Of these, by far the most abundant and destructive are the confused flour beetle, *Tribolium confusum* J. du V., and the rust-red flour beetle, *T. castaneum* (Herbst).

These insects are very hardy and able to subsist on any of a wide variety of foodstuffs, and through a world-wide commerce have been

[1] The writer acknowledges his indebtedness to the following persons for their cooperation in the investigations herein reported: To E. A. Back for originally planning and outlining the problem and for the general oversight of the work throughout its progress; to R. T. Cotton for many helpful suggestions; to S. A. St. George for the preparation of the descriptions of the larvae; to K. G. Blair, of England, for a specimen of *T. indicum* and information regarding this species and the synonymy of *T. castaneum*; to J. C. M. Gardner, of India, for specimens of *T. indicum* now in the U. S. National Museum; to the late A. M. Lea, of Australia, for information regarding *T. myrmecophilum*; to J. A. Hyslop for many of the distribution records and some of the records on foods; to Paul Bartsch, E. A. Chapin, and H. S. Barber for much helpful criticism regarding the taxonomic portion of the bulletin; and to H. B. Bradford for the line drawings.

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transported to regions which otherwise they might never have reached. Thus there are today not only records of their occurrence but numerous references to their destructiveness from practically every civilized country in the world.

SYNONYMIES AND TECHNICAL DESCRIPTIONS OF THE ECONOMICALLY IMPORTANT SPECIES OF TRIBOLIUM [2]

THE GENUS TRIBOLIUM MACLEAY

SYNONYMY OF THE GENUS

1825. *Tribolium* MacLeay (*67*)[3]
Genotype, *Colydium castaneum* Herbst (1797), type by subsequent designation, Lucas, 1855.

1833. *Margus* Dejean (*37*)
Genotype, *castaneus* Sch. (=*castaneum* Herbst), type by subsequent designation, Good, 1936.

MacLeay's description of *Tribolium* is sufficiently clear to leave little doubt that he was dealing with a specimen of the species treated as *Tribolium castaneum* in this bulletin. One disturbing factor is the designation of all tarsi as five-jointed. This cannot in itself be taken as constituting grounds for the rejection of the name *Tribolium*, since many mistakes were made by the early Coleopterists in regard to the number of tarsal joints. Concerning MacLeay's description of *Tribolium* Wollaston (*104, p. 491*) says:

> MacLeay, who was the first to characterize the group (in 1825), described it as pentamerous and placed it amongst the *Necrophaga*, which was clearly however an error—perhaps partially to be accounted for by the fact of his having but a single specimen to judge from.

Wollaston goes on to say that he had examined MacLeay's type specimen which was still preserved in the East India Co.'s Museum in London, and, "* * * the careless manner in which it is mounted conceals the hind tarsi altogether from view * * *."

It seems clear that MacLeay proposed his genus *Tribolium* for the true *Colydium castaneum* of Herbst (1797) and not for any other species the name of which he might have incorrectly synonymized with it. At the head of his description of the genus he says, "Genus TRIBOLIUM, Nobis. *Colydium* Herbst." He calls his species *castaneum*, and puts *Colydium castaneum* Herbst at the head of his synonymical list. Of the other synonyms, only one, *Trogosita ferruginea* Fab., is included without a question mark. But, since *Colydium castaneum* Herbst (1797) antedates *Trogosita ferruginea* Fab. (1801), and since *T. ferruginea* Fab. had never been associated with the genus *Colydium*, and since he calls his species by the same name

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[2] The manuscript for this bulletin as originally submitted to the Bureau of Entomology in March 1934 contained a complete revision of the genus *Tribolium*, consisting of the synonymies and descriptions of the 5 species previously known to the author, together with the description of 1 apparently new species. While the manuscript was being reviewed, a paper by Uyttenboogaart (*98*) appeared that covered much of the systematic work of this manuscript. *Tribolium destructor* Uyttenb. was found to be the same species as the apparently new one described in the original manuscript of this bulletin, so Uyttenboogaart's name was substituted as that of the describer. In the bulletin as now issued the systematic portion has been limited to the economically important species, so the species *T. indicum* Blair, *T. myrmecophilum* Lea, as well as Uyttenboogaart's *T. gebieni* are not treated here.

[3] Italic numbers in parentheses refer to Literature Cited, p. 51.

as that of Herbst, there is no question but that MacLeay would have designated *Colydium castaneum* Herbst as the type of his genus *Tribolium*, if it had been customary at that time to designate a genotype, which unfortunately was not the case. Furthermore, the first definite designation of a type for the genus *Tribolium* is that of Lucas (*66, p. 259*), who stated in 1855 "L'espèce type représentant ce genre, est le *Tribolium* (*Colydium*) *castaneum*, Herbst, Nature. Insect., tom. 7, p. 282, N°. 3, pl. 112, fig. 13 E (1797)."

The name *Margus* was first used by Dejean in 1833 (*37*) in the following manner:

Margus Dejean.
{Ferrugineus Fab. (Trogosita) India orient.
{castaneus Sch. (Tenebrio) Gallia.

He considered *castaneus* Sch. as a synonym of *ferrugineus* Fab. This entry was repeated in his 1837 catalog. In 1842 William Redtenbacher (*83*) used the name *Margus* as the generic name for what he considered a new species, *Margus obscurus*, but which later was found to be a synonym of *Tribolium madens* Charp. In 1845 L. Redtenbacher (*81*) separated *Margus* from *Tenebrio* in a descriptive key without mention of any species, and in 1849 (*82*) he gave a description of the genus *Margus* and of the species *ferrugineus* Fab. and *madens* Charp., which he listed under this genus. There can be no doubt that *Margus* of Redtenbacher is the *Tribolium* of this bulletin. The name *Margus* has since been used in a number of instances, especially in France, in treating of *Tribolium*. However, the writer has been unable to find a designation of a genotype for *Margus* in any of the literature dealing with this genus. There is, therefore, the choice between *ferrugineus* Fabricius and *castaneus* Schönherr, which Dejean thought to be synonymous. Since *Tenebrio castaneus* Schönherr (1806), as conceived by Schönherr, is a complex, embracing several species, the writer now restricts this name (since this has not been done before) to the fraction which Herbst called *Colydium castaneum* in 1797. Likewise, since *Margus* of Dejean (1833) embraces two species (*ferrugineus* Fab. and *castaneus* Sch.) the writer hereby selects *castaneus* Schönherr (=*castaneum* Herbst) as the genotype of *Margus* Dejean.

Regarding the *Stene* of Stephens (*95*) the writer is convinced from a study of Stephens' description that the specimens he had before him, and from which he made his description, were the *Tribolium castaneum* Herbst of this bulletin. However, since Stephens erected his genus for the *Tenebrio ferrugineus* of Fabricius, there is no alternative but to consider *Stene ferruginea* Stephens as a synonym of *Tenebrio ferrugineus* Fab. Since *Stene* is the first nonpreoccupied generic name for this species, *Stene ferruginea* (Fab.) becomes the valid name of the species originally described as *Tenebrio ferrugineus* by Fabricius in 1781. This species is now known to the writer only by the type specimen, which is considered a cucujid by prominent English coleopterists.

DESCRIPTION OF THE GENUS

Sexes externally alike. Color usually ferruginous, chestnut brown to black, sometimes with portions reddish. Body rather flattened or depressed. Clypeus much enlarged and with genae forming a shelflike projection extending around sides and front of head from eye to eye. Eyes rather large, emarginate or nearly divided by genae. Antennae 11-jointed, always enlarged toward tip, or clubbed; club 3- or 5-jointed or gradual, but never 2-jointed. Labrum short, transverse; mandibles short, equal in the two sexes. Prothorax nearly square or slightly wider than long, weakly bisinuate at base, rounded on sides, punctate or rugulose. Legs sparsely hairy, front tibia slightly enlarged toward tip; tarsi slender, middle coxa without trochantin. Elytra punctate-striate, sometimes rugulose, the intervals more or less raised in sharp carinae; epipleurae very narrow at tip. Wings present, usually functional. Ventral surface of abdomen weakly punctate. Length 3 to 6 mm.

KEY TO THE SPECIES OF TRIBOLIUM

1. Some or all of elytral intervals more or less raised or carinate; terminal joint of antennae either square, rounded, or largest at base; body not broad and rounded ---------- Subgenus *Tribolium* -- 2.
   All intervals of elytra smooth and flat; terminal joint of antennae small and in the shape of an inverted triangle; body broad and rounded -- Subgenus *Lemum* ---------- 7.

2 (1). Body uniformly ferruginous ---------- 3.
   Body black, maroon, or dark castaneous ---------- 5.

3 (2). Length 3.0 to 3.9 mm; punctation moderate, prothorax smooth and shiny; intervals of elytra moderate ---------- 4.
   Length 5.0 to 5.5 mm; punctation coarse and close; prothorax roughened and dull; elytral intervals raised into rather sharp carinae ---------- *gebieni*.

4 (3). Antennae with a distinct three-jointed club; space separating eyes ventrally equal to diameter of eye; eyes not margined above; genae fairly prominent ---------- *castaneum*.
   Antennae gradually enlarged; space separating eyes ventrally equal to three times the diameter of eye; eyes margined above; genae very prominent ---------- *confusum*.

5 (2). Body dark maroon or dark casteneous; antennae gradually enlarged or with an indistinct five-jointed club; space separating eyes ventrally not more than twice the diameter of eye; eyes margined above ---------- 6.
   Body black, appendages reddish; antennae with a distinct three-jointed club; space separating eyes ventrally equal to about three times the diameter of eye; eyes not margined above ---------- *madens*.

6 (5). Length 4.5 to 5.5 mm; color dark maroon with appendages lighter; first and second intervals of each elytron smooth; prothorax not rugulose; space separating eyes ventrally equal to nearly two times the diameter of eye ---------- *destructor*.
   Length 3.2 to 4.2 mm; color uniformly dark castaneous; all elytral intervals raised into sharp carinae and very prominent; prothorax rugulose; space separating eyes ventrally slightly less than the diameter of eye ---------- *indicum*.

7 (1). Tibiae stout; hind tarsi robust, first joint short, somewhat triangular; apex of prothorax narrower than base; scutellum very small, semicircular; space separating eyes ventrally equal to one and two-thirds times the diameter of eye; length 4.3 to 4.6 mm ---------- *myrmecophilum*.

SYNONYMIES AND DESCRIPTIONS

TRIBOLIUM CASTANEUM (HERBST)

SYNONYMY

1797. *Colydium castaneum* Herbst (*50, pt. 7*).
1806. *Tenebrio castaneus* Schönherr (*90, p. 153*).
1810. *Phaleria castanea* Gyllenhal (*49*).
1821. *Uloma ferruginea* Dejean (*36*).
1825. *Tribolium castaneum* MacLeay (*67*).
1833. *Margus castaneus* Dejean (*37*).
1839. *Stene ferruginea* Westwood (*102*).
1854. *Tribolium ferrugineum* Wollaston (*104*).

A list of the names usually cited as synonyms of *T. castaneum* (Herbst) but which do not refer to this species is given in table 1.

TABLE 1.—*List of names wrongly synonymized with Tribolium castaneum (Herbst)*

Date	Name and author	Habitat	Collection of	Remarks
1775	*Dermestes navalis* Fab.	New Zealand	Banks	Probably a dermestid. See *D. navalis* Fab. 1781 and 1787, and *Lyctus navalis* Fab. 1775 and 1787.
1781	do.	do.	do.	Text same as *D. navalis* Fab. 1775 and 1787.
1781	*Tenebrio ferrugineus* Fab	Equatorial Africa	do.	Cucujidae, teste Waterh. 1896, Champ. 1896, Blair 1913.
1787	*Dermestes navalis* Fab.			Text same as *D. navalis* Fab. 1775 and 1781. See *Lyctus navalis* Fab. 1792.
1787	*Tenebrio ferrugineus* Fab.	Saxony	Hybner	Homonym of *T. ferrugineus* Fab. 1781. See *T. ferruginea* Fab. 1792.
1792	*Trogosita ferruginea* Fab.	Equatorial Africa	Banks	Synonym of *Tenebrio ferrugineus* Fab. 1787, teste Fab.
1792	*Lyctus navalis* Fab.	New Zealand	do.	Antennal club 2-jointed. Synonym of *D. navalis* Fab. 1787, teste Fab.
1792	*Dermestes navalis* Herbst.	do.	do.	Synonym of *D. navalis* Fab. 1775, 1781, 1787, teste Herbst.
1792	*Ips cinnamomea* Herbst.	Germany	Hellwig	Illustration cannot refer to a *Tribolium*.
1795	*Tenebrio ferrugineus* Olivier.	Equatorial Africa.	Banks	Synonym of *T. ferrugineus* Fab. 1781, 1787, Linn. 1790 and *Trogosita ferruginea* Fab. 1792, teste Olivier.
1798	*Ips testacea* Fab.	Eastern India	Daldorf	See *Trogosita ferruginea* Fab. 1801.
1801	*Trogosita ferruginea* Fab.	India		Synonym of *T. ferruginea* Fab. 1792, *Lyctus navalis* Fab. 1792, *Ips testacea* Fab. 1798, teste Fab.
1806	*Tenebrio ochraceus* Melsh	Pennsylvania		Catalog reference only.
1812	*Tenebrio bifoveolatus* Duft.	Austria	Duftschmid.	Length $2\frac{2}{3}$ mm. *Palorus* teste Chapin.
1832	*Stene ferruginea* Stephens	England	Stephens	Genus *Stene* created by Stephens for *Tenebrio ferrugineus* Fab.
1836	*Uloma ochracea* Knoch.	North America		Catalog reference only.
1836	*Uloma rubens* Dej.		Dejean	Do.
1840	*Uloma rubens* Cast.	North America	do.	Length $6\frac{3}{4}$ mm, width $2\frac{1}{3}$ mm. Probably *Uloma*.
1847	*Margus ferrugineus* Kuster.	Europe		Length $2\frac{2}{3}$ mm, width $\frac{2}{3}$ mm. Probably *Palorus*.

The species *Tribolium castaneum* has been generally known in North America and elsewhere as *Tribolium ferrugineum* Fab. (1781 or 1787), but it is very evident that the name *ferrugineum* Fab. cannot be retained. The type of *Tenebrio ferrugineus* Fab. (1781) was examined by Waterhouse (*100*) in 1896 and found to be quite different from the insect known as *Tribolium ferrugineum* Fab. In this type specimen, in addition to other characteristics excluding it from the Tenebrionidae, all of the tarsi were four-jointed, and Waterhouse placed it among the Cucujidae. Champion (*16*) and Blair (*9*) also examined this type specimen and corroborated the opinion of Waterhouse that it was a cucujid. Champion, Waterhouse, and Blair, all seem satisfied that the specimen in question is the identical one described by Fabricius in 1781, and, although the identity of any specimen is, at best, very uncertain after 115 years, the concerted opinion of these three eminent coleopterists as to the specimen's identity and its proper classification seems of sufficient weight to insure its acceptance. Since 1896 the description of *Tenebrio ferrugineus* Fab. (1787) has been generally accepted as the original description of the species. However, this name is an exact homonym of that of the 1781 insect and could not be used even if Fabricius had been dealing with another species. Whether Fabricius really was dealing with another species is not certain although Blair (*9*) thinks not. He says:

> The description of *Trogosita ferruginea*, Ent. Syst. I, 1792, quite disposes of this possibility, for here it is definitely synonymised with the *Tenebrio ferrugineus* of the "Mantissa", and Fabricius continues: "Habitat *in Africa aequinoctiali Mus. Dom. Banks*, in Americae Insulis Dr. Pflug," the words in italics being obviously quoted from the Species Insectorum, 1781. It is perfectly clear, therefore, that Fabricius supposed that he was dealing with one and the same species in these three instances. Furthermore, this conclusion is borne out by Sherborn's "Index Animalium" which quotes *Trogosita ferruginea* (1792) as synonymous with *Tenebrio ferrugineus* (1781), and in the "Epitome Entomologiae Fabricianae", by Bergsträsser, p. 18, where *Trogosita ferruginea* is the only one that appears. From these facts, then, it is evident that the name *ferrugineum*, F. as applied to the *Tribolium*, can have no *locus standi* whatever.

Dermestes navalis Fab. (1775) has been thought by some authors to refer to the present species. The listing of *Lyctus navalis* as a synonym of *Trogosita ferruginea* by Fabricius in 1801 may be the basis for the use of the name *navalis* by Reitter in 1911. That this cannot be correct is evident for several reasons. The description states that it is of the form of *Dermestes murinus* but one-fourth smaller, which very evidently does not refer to a *Tribolium*. In 1792 Fabricius described a *Lyctus navalis* with a 2-jointed club on the antenna and synonymized it with his third description of *Dermestes navalis* (1787). His three descriptions of *Dermestes navalis* (1775, 1781, and 1787) are almost identical in wording, name, habitat, and collection, except that no habitat or collection is given for the 1787 description. From this it seems perfectly evident that Fabricius was dealing with the same species and perhaps the same specimen in all four of his descriptions of *navalis*, and that it cannot be the present species is certain because he described it as having a 2-jointed club on the antenna instead of a 3-jointed one.

Ips cinnamomea Herbst (1792) is sometimes given as a synonym but certainly cannot refer to this species because Herbst (*50, pt. 4*) begins by saying that it has exactly the form but not the size of the first (*Ips quadripunctata*), which certainly differs very greatly from a *Tribolium*, and because from the figure given one needs to stretch his imagination considerably to place it anywhere near *Tribolium*.

The description of *Colydium castaneum* Herbst (1797) fits the present species very well with one exception. His description of the tarsi (*50, pt. 7*) states "die Füsse sind wie gewöhnlich", which is four joints for all of the tarsi in the genus *Colydium*. However, as has been stated, the designation of any certain number of tarsal joints to a beetle, especially a tenebrionid, by these early coleopterists should not be taken too seriously. In this respect it is significant to note that MacLeay, in proposing his genus *Tribolium* for the *Colydium castaneum* of Herbst, which was originally described as having all the tarsi 4-jointed, nevertheless designated all the tarsi as 5-jointed. Apparently, because of imperfect lenses, neither of these authors was able to determine the exact number, and neither suspected that his insect might be heteromerous. Furthermore, Herbst states that his insect was taken as a museum pest, damaging insects in a collection. After eliminating the dermestids, to which the description cannot possibly refer, there are left, in addition to this *Tribolium*, so few insects known to be museum pests that it is an easy matter to see that none but *T. castaneum* fits the description. Finally, Herbst's illustration of his *Colydium castaneum* (fig. 1) is sufficiently clear to be recognizable as referring to *T. castaneum*, even without the description or food record; and when considered in connection with the description and especially with the remark as to its food in this particular instance, all question as to its identity is removed.

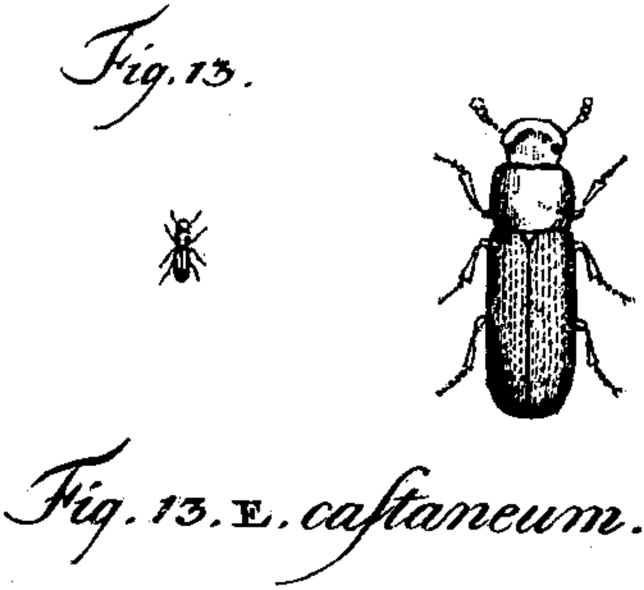


FIGURE 1.—Reproduction of Herbst's original illustration of *Colydium castaneum* (50, *pt.* 7), 1.82 times the size of the original illustration.

DESCRIPTION

(Fig. 2.)

Color uniformly ferruginous or reddish brown.

Head: Clypeus fused with front. Genae in front of eyes moderately widened and forming an angle of about 60° with the eye, this shelflike projection extending forward from eyes and continuing around the clypeus but truncate and not particularly expanded at front of head. Surface of head irregular; a shallow, transverse depression running across head in front of eyes and another just back of eyes; upper surface rather densely punctate, under surface finely and sparsely punctate. Eyes emarginate, the emargination extending backward for about one-third length of eye. Epicranium not margined above eye, front and eye forming a nearly continuous line. Viewed from below, eyes transversely ovate and very large, the width of each eye being equal to or only slightly less than the distance separating them. Antennae with the three terminal joints suddenly enlarged, forming a distinct club, the ninth joint being nearly twice as wide as the eighth; terminal joint transversely rounded, or transversely ovate. Labrum very short, transverse, hairy. Mandibles short, bifid at the tip. Maxillary palpi with last joint oval, obtuse at apex. Labial palpi with last joint subovate.

Prothorax widest at middle, front margin little or no wider than rear margin; sides rounded. Front angles gradually rounded, front margin nearly truncate; rear angles slightly obtuse; rear margin strongly bisinuate. Moderately punctate above, less so below. Scutellum nearly semicircular or semihexagonal with rounded angles. Elytral intervals fairly prominent but usually less so than the lines of punctures, which are of a darker color than other parts of the elytra; these characters rather variable. Margins of epipleurae extending slightly below lateral margins of body except caudad of third abdominal segment. Wings fully developed, functional. Legs rather slender, front tibiae slightly widened apically, fore and middle tibiae moderately serrate on outer margins; all tibiae with two short terminal spines; all tibiae and tarsi sparsely ciliated.

Abdomen finely punctate over entire surface. Lateral margins of first and second segments smooth, parallel; third slightly converging, with a very small rounded projection on each side at apex; fourth short, also more contracted laterally, with a small, rounded projection on each side at two-thirds the distance from base to apex; fifth semicircular, the projections slightly larger than on fourth segment and situated near base, with a slight indentation immediately to the rear of these projections. Sutures between all segments parallel, except at lateral margins. Fourth segment hardly more than one-half the length of the second; third three-fourths the length of the second.

Length 3.00 to 3.73 mm, average 3.323 mm; width 0.97 to 1.26 mm, average 1.143 mm.

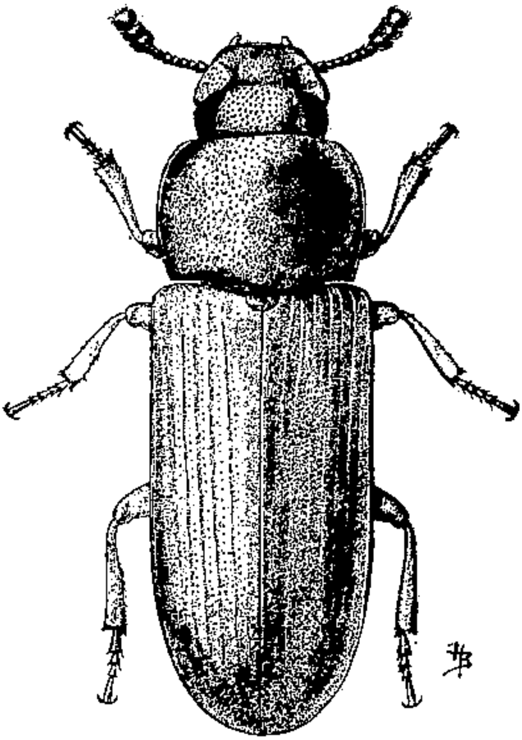


FIGURE 2.—*Tribolium castaneum:* Adult, × 28.

Habitat.—Cosmopolitan, in cereal products, etc.
Type locality.—East Indies.

TRIBOLIUM CONFUSUM JACQUELIN DU VAL

SYNONYMY

1854. *Tribolium ferrugineum* Mulsant, (*70*).
1868. *Tribolium confusum* Jacq. du Val, (*55*).
1891. *Tribolium* (*Stene*) *confusum* Seidlitz, (*91*).

Mulsant in 1854 misidentified the present species, calling it *Tribolium ferrugineum* Fab. The fact that the name *T. ferrugineum* was applied to this has therefore no status as far as its antedating the present name is concerned.

The name *Stene* was incorrectly used by Seidlitz in 1891 (*91*) and 1894 (*92*) as a subgeneric name for *T. confusum* J. du V., which he separated from *T. castaneum* Herbst and *T. madens* Charp. on the basis of antennal characters. He disregarded the fact that Stephens' *Stene* actually referred to *T. castaneum* and so could not be used as he suggested even if, as was shown in the discussion of the synonymy of the genus, this name was not entirely thrown out of the group for nomenclatorial reasons.

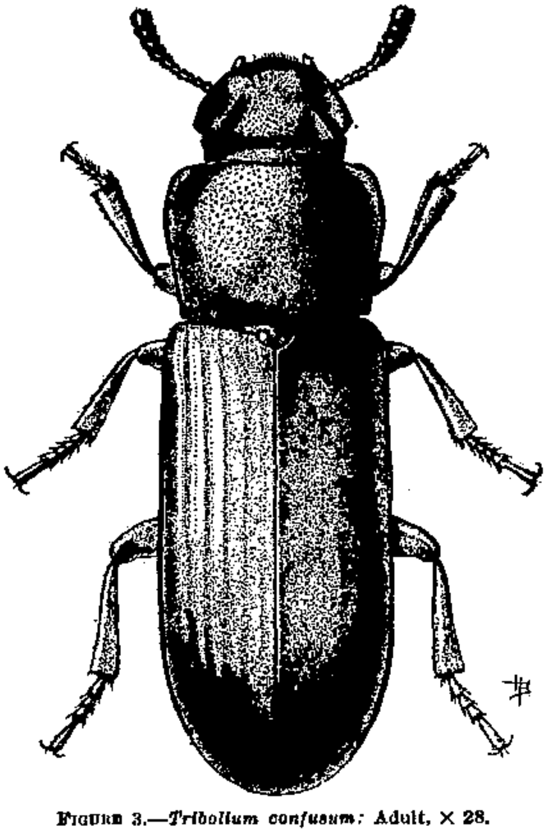


FIGURE 3.—*Tribolium confusum:* Adult, × 28.

DESCRIPTION

(Fig. 3.)

Color fairly uniform, reddish brown or ferruginous.

Head: Genae in front of eyes distinctly widened, jutting out at nearly a right angle with them and, with the clypeus, forming a thin, shelflike projection around front of head, the expanded clypeus rounded anteriorly. Eyes decidedly emarginate, the emargination extending backward to middle of eye. Epicranium sharply margined immediately above the eye, forming a horizontal carina slightly jutting out over the eye. These characters make the eyes appear much smaller than in *castaneum.* Viewed from below, the eyes are rounded, the space between the eyes being nearly three times the observed width of the eye. Antennae gradually enlarged toward tip, the expansion taking place mainly in the seventh to tenth joints, but the ninth only slightly larger than the eighth. Terminal joint round or transversely rounded. Antennae sparsely hairy. Mouth parts similar to those of *castaneum*.

Prothorax widest at apical third, distinctly wider at front margin than at rear margin; front angles sharply rounded, projecting slightly anterior to the straight line forming the remainder of the front margin; hind angles usually right angles, rear margin weakly bisinuate. Scutellum semihexagonal. Elytral intervals fairly prominent, usually more noticeable than the lines of punctures. Margins of the epipleurae nearly coinciding with those of the sternites. Wings fully developed. Legs similar to those of *castaneum*.

Abdomen similar to that of *castaneum* but with the projections on the third, fourth, and fifth segments slightly more pronounced.

Length 3.09 to 3.82 mm; average 3.457 mm; width 1.08 to 1.26 mm; average 1.179 mm.

Habitat.—Cosmopolitan, in cereal products, etc.

Type locality.—France.

TRIBOLIUM MADENS (CHARPENTIER)

SYNONYMY

1825. *Tenebrio madens* Charpentier, (*25*).
1832. *Uloma madens* Krynicki, (*61*).
1842. *Margus obscurus* Redtenbacher, (*83*).

DESCRIPTION

(Fig. 4.)

Color of body dull black; legs, antennae, and mouth parts reddish.

Head closely but finely punctate uniformly over the dorsal surface, the pits shallow and usually elongate. Ventral surface moderately punctate with fine pits. Clypeus concave along center of front margin, the sides directly above the base of antennae also slightly concave and raised. Clypeus separated from genae by an indistinct suture but not separated from frons. Frons smoothly rounded or slightly arched. Genae scarcely projecting from curvature of the eyes. Eyes divided by genae for only about one-fourth of their length. Epicranium not at all margined above eyes. Eyes ventrally small and rounded. Space separating them usually 2½ to 3½ times the diameter of eye. Antennae with a very distinct three-jointed club as in *T. castaneum*. Antennal joints narrow up to eighth, which is slightly wider than long, ninth, tenth, and eleventh flattened and much wider than long. Terminal joint large, as broad as tenth and truncate on end. Labrum transverse but rounded on front. Last joint of maxillary palpi slender. Width of head across eyes 0.63 to 0.74 mm; width across genae scarcely any greater.

Prothorax one and one-third times as broad as long, somewhat flattened. Fairly evenly punctate over entire dorsal surface, but somewhat more densely so toward sides; pits hexagonal. More deeply and coarsely punctate than that of *T. castaneum*. Front margin very slightly and evenly bowed forward. Margins of front angles slightly but definitely jutting forward. Sides of prothorax rather sharply margined. Side margins convex to one-third from front angles thence converging regularly to hind angles which are slightly obtuse. Rear margin feebly bisinuate. Base of prothorax impressed on each side of center. Ventral surface of prothorax closely and deeply punctate. Scutellum broadly semihexagonal. Elytra somewhat broader in proportion to length than in *T. castaneum*. Broadest at one-third from apex. First and second intervals smooth, third and fourth slightly raised, fifth, sixth, and seventh slightly carinate, eighth less so, ninth and tenth nearly smooth. Finely and closely punctate, usually with two rows of pits between each interval, those on the disk indistinct. Epipleura narrowing gradually from base to apex. Margins of epipleura nearly coinciding with those of sternites. Wings well developed, functional. Legs similar to those of *T. castaneum* but with serrations of front and middle tibiae absent or nearly so. Tibial spines straight.

Abdomen evenly and finely punctate over entire ventral surface. Lateral rounded projections more reduced than those of *T. castaneum*. Fifth segment with a shallow impression on each side of center. Average length of abdominal segments: first, 0.44 mm; second, 0.35 mm; third, 0.32 mm; fourth, 0.24 mm; fifth, 0.32 mm; total length of abdomen, 1.67 mm.

Length, 3.6 to 4.4 mm; width across elytra, 1.2 to 1.6 mm.

Habitat.—Europe, North America, Egypt. Under bark and in rotting logs, occasionally in flour and seeds.

Type locality.—Silesia.

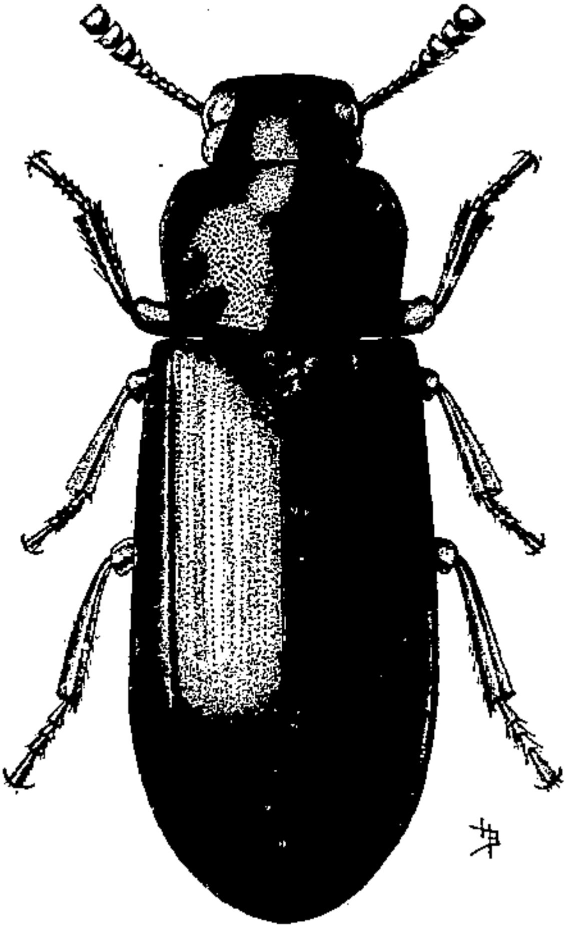


FIGURE 4.—*Tribolium madens:* Adult, × 28.

TRIBOLIUM DESTRUCTOR UYTTENBOOGAART

SYNONYMY

1933. *Tribolium destructor* Uyttenb. (*71, pp. xli–xlii*)

DESCRIPTION

(Fig. 5.)

Color of body dark maroon shining; appendages lighter and more reddish.

Head fairly strongly punctate, the pits elongate and often running together, especially on frons, to form minute, crooked grooves. Ventral surface of head sparsely and finely punctate. Clypeus truncate in front, sides rounded, separated from genae by a suture, but not separated from frons. A shallow transverse impression running across the head from front of one eye to the other, and another, incomplete, shallow transverse impression between frons and apex. Eyes divided by the genae for about three-fifths of their length; narrowly margined above. Ventrally moderate in size, the space separating them being equal to from 1½ to 2 times the diameter of each eye. Antennae gradually enlarged or with a very indistinct 4- or 5-jointed club which is sparsely hairy. First joint of antennae concealed by clypeus, joints 1 to 5 narrow, the sixth beadlike, the seventh and eighth progressively broader, the ninth and tenth twice as broad as long, terminal joint broadly rounded to oblong. Labrum short and very transverse; hairy. Mandibles large, bifid, and pointed at tip. Maxillary palpi large, broadly oval. Width of head across genae 0.82 to 0.99 mm; width across eyes 0.80 to 0.93 mm.

Prothorax 1.00 to 1.25 mm long, 1.25 to 1.55 mm broad; closely and coarsely punctate or pitted, but with the portions between pits smooth and shining. Pits hexagonal or diamond shaped. Upper surface of prothorax moderately arched, sides rounded, broadest one-third from apex; sides of prothorax margined, more strongly so at the front angles, which project forward rather prominently; rear angles obtuse, rear margin bisinuate. Two prominent longitudinal depressions extend slightly forward from the base, one on each side of the midpoint, half way between it and the rear angles. Ventral surface of prothorax closely and coarsely punctate. Ventral surface of mesothorax and metathorax moderately punctate. Scutellum broadly semihexagonal. Elytra more rounded than those of *T. castaneum*. The first two intervals between the rows of pits nearly flat and without carinae, the third elevated at base but less so toward the apex, the fourth, fifth, and especially the sixth and seventh intervals distinctly carinate, the eighth less so, and the ninth nearly flat. Disk of elytra with indistinct rows of pits together with a general punctation and smaller pits. Rows of pits between fourth and seventh intervals distinct and consisting of a central distinct row of pits together with an accompanying row of pits on either side directly at base of each carina. Epipleurae moderately broad back to base of the last abdominal segment, thence very narrow. Margins of epipleurae nearly coinciding with sides of abdominal segments. Wings well developed. Legs similar to those of *T. castaneum*, but with serrations of front and middle tibiae absent or nearly so and with the ventral groove of the prothoracic femora more pronounced. All tibiae terminated by two straight spines, the anterior spine of prothoracic tibiae much larger than the others.

Abdomen moderately pitted over entire ventral surface. Length of first segment with intercoxal process 0.46 to 0.58 mm, second segment 0.40 to 0.43 mm, of third segment 0.36 to 0.39 mm, of fourth segment 0.26 to 0.29 mm, of fifth segment 0.38 to 0.43 mm, total length of abdomen 1.8 to 2.1 mm. Margins of abdominal segments differing from those of *T. castaneum* in that the lateral rounded projections are absent or very much reduced on the third and fourth segments and reduced on the fifth.

Length 4.3 to 5.4 mm, width across elytra 1.4 to 1.8 mm.

Habitat.—Recently found to be a pest in seeds and various cereal products in Germany and the Netherlands.

Type locality.—Erfurt, Germany.

HISTORY AND ECONOMIC IMPORTANCE OF THE GENUS TRIBOLIUM

COMMON NAMES

The flour beetles are known by a variety of common names. Millers refer to species of *Tribolium* and other closely related beetles of similar appearance as "flour beetles", "flour weevils", "red weevils", or "bran bugs." Grain inspectors know them as bran bugs.

The approved common name for *T. confusum* is "the confused flour beetle." It has also been referred to by one of the earlier American entomologists as "the pollard weevil", while in Germany this species is commonly called "the American rice-flour beetle." The name "confused flour beetle" is the natural outgrowth of its scientific name which was chosen by Jacquelin du Val because the species had until then been confused with the very similar *T. castaneum.* The accepted common name of the latter is, "the rust-red flour beetle", which is appropriate considering the insect's color but does not differentiate it from its many similarly colored relatives. Other common names for this species found in less recent American literature are "wee flour beetle", "red flour beetle", "ferruginous flour beetle", "brown grain beetle", and "the weevil." In Germany it is commonly called "the red-brown rice-flour beetle."

The common names by which *T. madens* has been called are "the black flour weevil", a name given to it by Johnson in 1897 (*58*), "the black flour beetle", by Chittenden in 1911 (*30*) and "the black-brown rice-flour beetle", by Zacher (*108*) in 1927. The first name is inappropriate, however, as none of this group have any relation to true weevils. Of the other two names the writer prefers the black flour beetle, a name which adequately describes the insect and also is in harmony with the names given to other *Tribolium* and closely related beetles, which are all known as flour beetles.

FIGURE 5.—*Tribolium destructor:* Adult, × 12.

No common names have as yet been proposed for the other species of *Tribolium*, but since these species, with the exception of *T. destructor* Uyttenb., are of no economic importance, there is no need for common names by which to designate them.

PLACE OF ORIGIN OF THE GENUS

As with most stored-product insects, the question of the place of origin of *Tribolium* is very difficult to solve because their distribution by commerce has long since made them cosmopolitan. There is only one definite record which throws any light on the subject. Andres (*3*) records the finding of specimens of *Tribolium* in a Pharaonic tomb of about 2500 B. C. At that time commerce, the only means by which these insects are distributed, was largely restricted to the Mediterranean region and southern Asia. Another hint is given by Blair (*10*) in evidence showing that *T. castaneum* is commonly found in the wild state in wood in India. It is also found in such situations in North America and elsewhere, but not at all commonly. In the same article Blair described a closely related species, *T. indicum*, from the same country and with the same habitat which does not occur in stored products. From these facts it seems probable that these beetles originated somewhere in the general region comprising India, southwestern Asia, and the eastern Mediterranean lands.

The fact that *T. gebieni* was described from Paraguay and so far has not been recorded elsewhere has no meaning whatever so far as its origin is concerned. It was not described until 1933, and there is no indication of its habitat or food habits. It seems quite probable that *T. gebieni* is a native of some other country where it still awaits discovery and that it has been transported to Paraguay by commerce.

Another species, *T. myrmecophilum*, is known only as an inhabitant of ants' nests in southeastern Australia and cannot fit into any present theory as to the origin or original habitat of the genus. It may be that later this species will be discovered in other localities and with other habits, or may be placed in a separate genus, but at present the writer does not propose to offer any explanation for this seeming discrepancy in his theory.

It is almost certain that before the advent of civilized man the members of this group lived under bark and in old logs. In that case

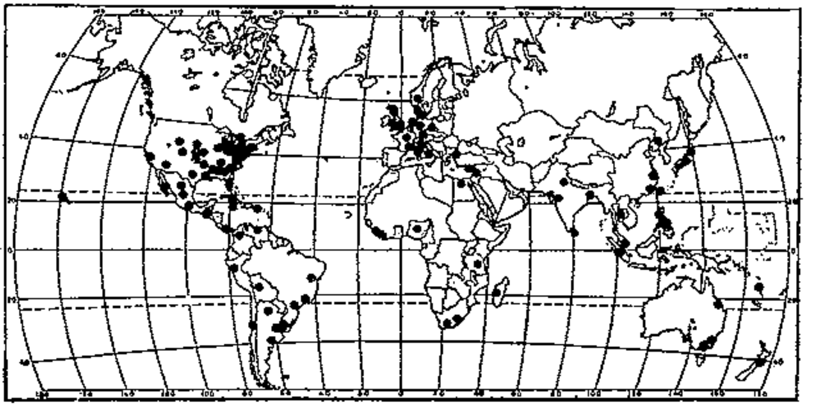


FIGURE 6.—Distribution of *Tribolium castaneum* as shown by records of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. In the United States each infested State is represented by a dot, the infestation being shown more in detail in figure 8.

their food habits were probably those of scavengers, but of this there is no certainty. With very few exceptions, the beetles of the subfamily Ulominae, of which *Tribolium* is a member, occur either as pests of stored products or else under the bark of trees and in rotting logs. It seems very probable that the members of this group originally lived in the latter habitat and that the flour-feeding species have since become adapted to their present mode of life. The genus *Tribolium* presents all gradations between the two. *T. indicum* lives under bark only, *T. madens* usually occurs there but has been taken in seeds and in meal on a few occasions; while *T. confusum* and *T. castaneum* are essentially pests of stored products, although sometimes found under bark, and *T. destructor* has so far been recorded only from seeds and other stored products.

DISTRIBUTION

Tribolium confusum and *T. castaneum* are cosmopolitan, occurring all over the world wherever stored cereal products are to be found (figs. 6, 7, 8, and 9). As they live inside of buildings and may easily be carried from place to place in small quantities of foodstuffs, these beetles are likely to be recorded from practically any part of the world. The failure of the world-distribution maps to show any appreciable difference in the northerly distribution of the two species

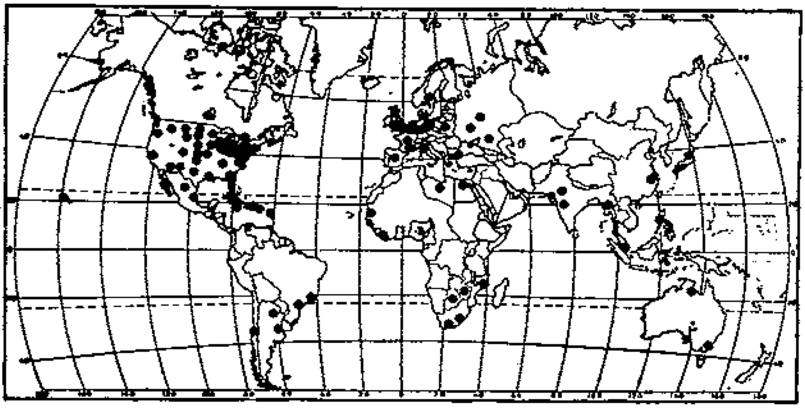


FIGURE 7.—Distribution of *Tribolium confusum* as shown by records of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. In the United States each infested State is represented by a dot, the infestation being shown more in detail in figure 9.

is due to the fact that either species may be introduced and become established in heated buildings in climates much colder than they could ordinarily tolerate. Records in the United States indicate that

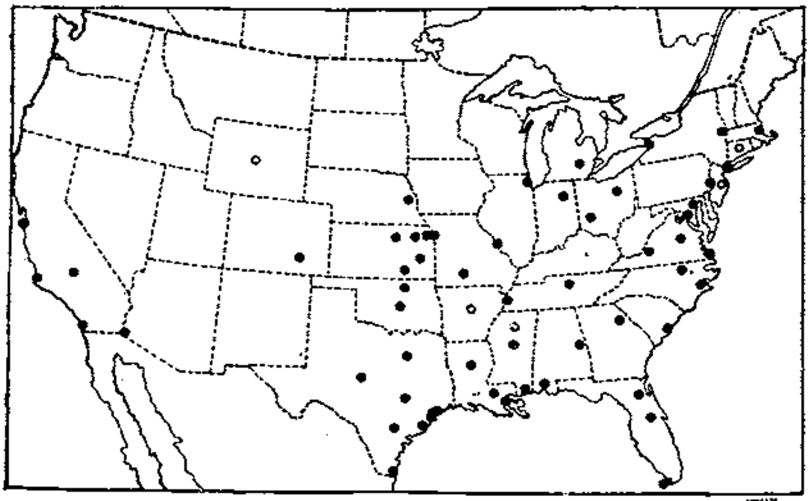


FIGURE 8.—Distribution of *Tribolium castaneum* in the United States.

temperature has quite an effect on distribution. *T. castaneum* is essentially an insect of warm climates, and, although sometimes recorded from Canada and other northern countries, it is evidently not a permanent resident north of the fortieth parallel in eastern

United States except in heated buildings. *T. confusum*, on the other hand, is more frequently found in the northern part of the United States than in the southern part. From 37° to about 40° N. both species occur commonly, while south of 37° *confusum* gradually

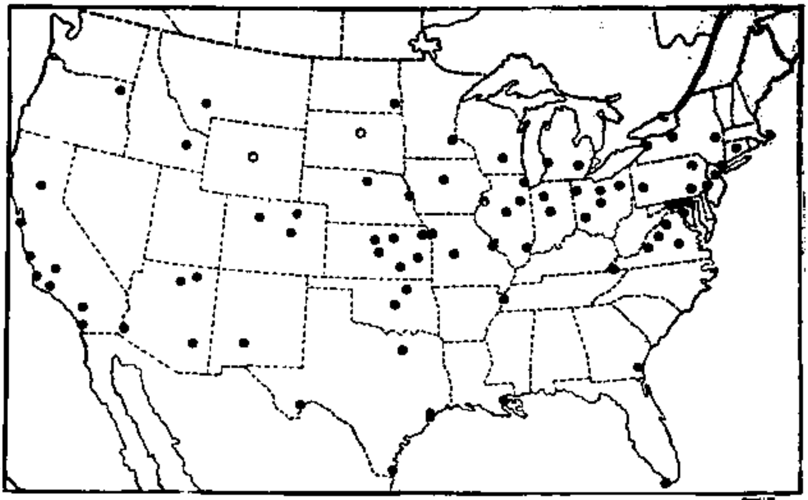


FIGURE 9.—Distribution of *Tribolium confusum* in the United States.

becomes less common and in the Gulf States is largely replaced by *castaneum*.

The localities from which *T. madens* has been recorded are shown in figure 10. It would appear to be of more northerly distribution

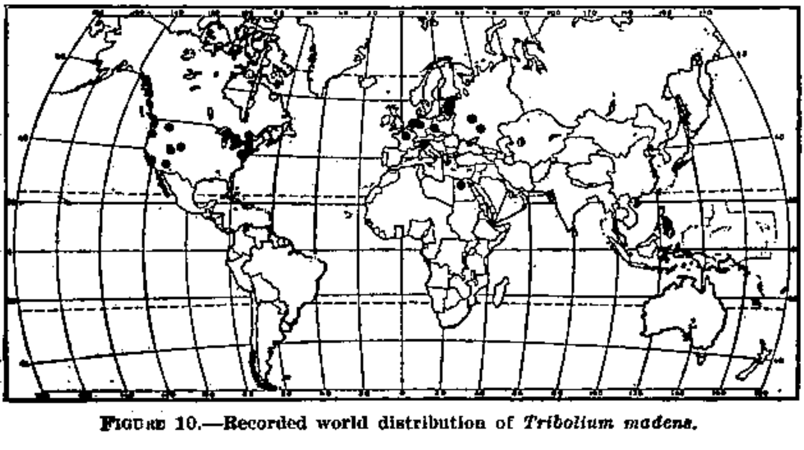
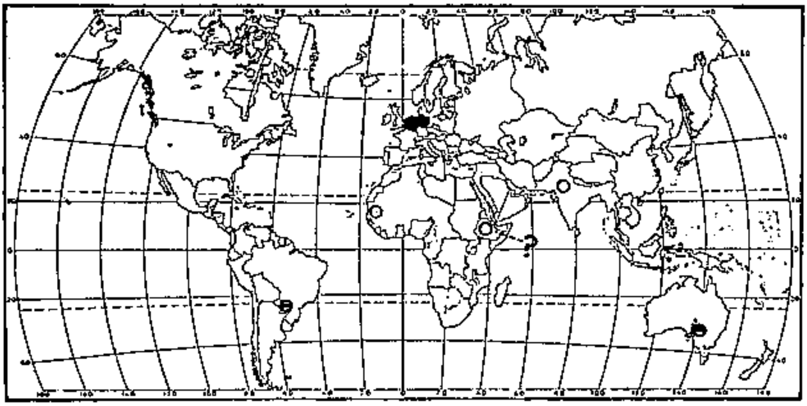


FIGURE 10.—Recorded world distribution of *Tribolium madens*.

and able to withstand greater extremes of cold than any of the other species of *Tribolium*. In this connection it should be remembered that the majority of the records of *T. madens* are from specimens taken out of doors, while all of the records of *T. castaneum* and

T. confusum from northerly localities are from specimens taken indoors in heated buildings.

T. destructor is found in Germany and the Netherlands; *T. indicum* has been recorded from India, Senegal, and possibly from Abyssinia; *T. myrmecophilum* is known only from southeastern Australia; and *T. gebieni* Uyttenb. is recorded from Paraguay (fig. 11).



● —T. DESTRUCTOR UYTTENB. ○ —T. INDICUM BLAIR
ϴ —T. GEBIENI UYTTENB. ⊖ —T. (LEANUM) MYRMECOPHILUM LEA

FIGURE 11.—Recorded distribution of other species of *Tribolium*; the species *destructor, indicum, gebieni,* and *myrmecophilum* being indicated by symbols.

HISTORICAL NOTES

DISCUSSIONS OF TRIBOLIUM CASTANEUM AND T. CONFUSUM

Perhaps the most interesting record concerning *Tribolium* is one that goes back over 4,400 years. Andres (*3*) gives the following account:

> Mr. An. Alfieri has supplied me with the following interesting facts in connection with *Tribolium* beetles found in an ancient burial monument. The beetles were found in a jar which probably contained grains or flour in a pharaonic tomb of the 6th Dynasty (about 2,500 years A. C.). Although these insects were still fairly decently preserved it is impossible to establish whether they belong to *ferrugineum* or *confusum* owing that legs and antennae are missing. In any case it is interesting to note that the genus *Tribolium* existed in the Nile Valley since that time and cannot be considered of a recent introduction into the country through importation.

There seem to be no other records antedating the description of *T. castaneum* by Herbst in 1797. It was first recorded in North America in 1835 by Thomas Say (*88*) under the name *Uloma ferruginea* Fab. A good description was given by Wollaston (*104*) in 1854, Lucas (*66*) in 1855, gave a good account of its metamorphosis, while Schiødte (*89*) gave a fine description of the larva in 1878. In 1854 Mulsant (*70*) gave a good description of *T. confusum* under the name of *T. ferrugineum*.

The first to notice a variation in structure of his specimens was Wollaston (*105, p. 496, footnote*) who evidently had specimens of

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both *castaneum* and *confusum* before him, but thought *confusum* to be the male of *castaneum* instead of a new species. His account follows:

In every diagnosis to which I have had access (including my own, in the "Ins. Mad.") the sexes of *Tribolium* are regarded as perfectly similar (externally) *inter se.* But an accurate inspection has lately convinced me that such is not, in reality, the case,—one of them (which I presume to be the male) being not only less opake and with its prothorax appreciably narrower behind, but having likewise its genæ just perceptibly more prominent and angular in front of either eye, and its antennal club much less abrupt, or more *gradually* formed (occasioned by the subclaval joint, or joints, being wider).

Four years later Jacquelin du Val (*55*) correctly interpreted this variation as constituting a new species and described it as *T. confusum,* the name being chosen because this species had until then been confused with *castaneum.*

One of the first important contributions to the biology of *Tribolium,* and the first from the North American continent, is that of Dugés (*39*) (1883), from Mexico. The first from the United States is that of Lintner (*65*) in 1885, in which he gave an account of the synonymy of *T. castaneum* and its distribution and damage, particularly in New York. Another important contribution to the biology of *T. castaneum* was by Kessler (*59*) in Germany. Some of the earlier American records on *T. castaneum* are those of Cook (*31*) and of Weed (*101*) in 1891, and Bruner (*13*) in 1893, all of which were general accounts concerning this species in various parts of the United States.

T. confusum was not recorded in North America as a distinct species until 1886 when Champion (*15*) recorded it from Mexico. It was recognized in the United States as distinct from *T. castaneum* in the fall of 1893. In 1895 the records of damage by *T. confusum* were numerous.

From 1895 to 1897 Chittenden (*26, 27, 28, 29*) gave the first really important contributions on the genus including data on the biology, distribution, and injury done by all three of the American species. Johnson published many records of injury by these insects beginning with a paper (*56*) in 1895. Quaintance in 1896 (*79*) and 1899 (*80*) published accounts of the biology of both species in Florida. The majority of the numerous short accounts of *Tribolium* between this time and that of Chapman's article in 1918 (*17*) are copied from Chittenden's papers. Good discussions on synonymy were given in 1896 by Champion (*16*) and Waterhouse (*100*) and by Blair (*9*) in 1913, while very acceptable descriptions of the three known species, with keys for identification, were given by Desbrochers des Loges (*38, pp. 27–30*) in 1902. *T. castaneum* was recorded in Hawaii by Kotinsky (*60*) as living in bee cells, as feeding on lac in India by Imms and Chatterjee (*54*) and by Roubaud (*87*) as doing considerable damage to peanuts in Senegal. Herrick (*51*) cited several instances of damage by these insects together with a short discussion of their biology. Barnes and Grove (*8*) in 1916 gave notes on the biology of several stored-grain insects in India including *T. castaneum,* and also presented work on chemical experiments, respiration, effect of humidity, and remedial measures.

Chapman (*17*) in 1918 made one of the most important contributions to date concerning the biology of *T. confusum*, including a good original account of the life history, food, relative infestation of wheat flour and wheat-flour substitutes, and methods of control.

Short articles on both species appeared in a bulletin by Back and Cotton (*5*) in 1922, a short account of the life history of *T. confusum* was given by Felt (*43*) in 1921, while the effect of *T. confusum* on flour was discussed by Payne (*76*) in 1925.

The more important recent articles on the biology of *Tribolium* are those by Burkhardt (*14*) and Kunike (*62*), giving good accounts of the biology of *T. confusum* in Germany; by Brindley (*12*), which gives much data on the life history and many measurements on the various stages of these beetles; by Good (*47*), in an article intended as preliminary to this bulletin giving a summary of biological experiments on both *T. confusum* and *T. castaneum*; and one by Park (*75*) in 1934, presenting an enlightening and critical analysis of all of the recent important papers on *T. confusum* as well as considerable valuable original data.

The subject of nutritional requirements has been investigated and discussed by Chapman (*19*) and by Sweetman and Palmer (*97*), while the effect of nutrition on sex is discussed by Holdaway and Smith (*53*).

The subject of ecology, and especially that part relating to growth of populations, has received considerable attention within the past few years. In this field, as in many others, the pioneer has been Chapman, whose articles on environment and increase of populations appeared in 1928 (*20*), 1929 (*21*), 1931 (*22*), 1933 (*23*), and 1934 (*24*). Allee (*2*) in 1931 discussed the growth of populations of *T. confusum*, basing his discussion largely on Chapman's work. A mathematical study of the growth of populations of *T. confusum*, also based on the work of Chapman, is presented by Gause (*46*), while Stanley (*93*, *94*) gives more extended mathematical treatises on this subject. Original investigations as well as analyses of previous work were presented in two papers by Park in 1932 (*73*) and 1933 (*74*) on the factors regulating initial growth of populations of *T. confusum*. The effect of moisture on the growth of populations was very well discussed by Holdaway (*52*) in 1932.

An article by Blair (*10*) gives valuable data on food and distribution as well as the original description of another species, *T. indicum*, and Uyttenboogaart (*98*) has presented a revision of the genus and a description of and data concerning *T. destructor*.

Laboratory studies of the effect of low temperature on *T. confusum* were reported by Payne in 1926 (*77*) and 1927 (*78*), while work on the resistance of *T. castaneum* to heat was given by Yokoyama in 1925 (*106*) and 1927 (*107*).

Much emphasis has been placed on the control of these very injurious beetles, but, as would be expected, very little of the work on control concerns *Tribolium* alone. On that relating mainly to *Tribolium* may be mentioned articles by Chapman (*17*), Lehman (*64*) on the use of paradichlorobenzene and naphthalene, DeCoursey (*35*) on trapping in corrugated paper, and by Richardson and Haas (*84*) on the use of pyridine and nicotine. Under the heading of Control Measures (p. 47) will be found references to the more practical discussions by recent investigators.

HISTORY OF TRIBOLIUM MADENS CHARP.

The first reference to *Tribolium madens* is the description by Charpentier (*25*) in 1825 of a specimen taken from a beehive in Silesia. Redtenbacher's description of *Margus obscurus* in 1842 (*83*) seems to be of this same species. His specimen was taken in Austria. There are various other records of *T. madens* in Europe, but it has usually been taken in rotting wood or similar situations where it was of no economic importance, although it has been recorded as doing damage to flour and cereal products in Russia. Descriptions of *T. madens* have been published by Seidlitz (*92*) and by Des Loges (*38, p. 29*).

The first American record for *T. madens* seems to be a catalog reference by LeConte (*63*) in 1866. Chittenden (*27*) gave a number of records for this species in the United States, but none of these concern cereal products, and he expressed the opinion that it was not found in such situations. Johnson (*57, no. 7*), however, cited a case where it was abundant and causing considerable trouble in a flour mill in Utah in the summer of 1895 and recorded in 1897 (*58*) receiving it in flour and mill products from the States of Montana and Washington. Two specimens in the collection of the United States National Museum were, according to the label, taken in ground cereal in a flour mill at La Grande, Oreg., in August 1897. Other specimens from Bonner, Mont., were taken in meal and cereals. Essig (*42*) referred to it as "another cosmopolitan species" which "occurs in cereals in the west", and from Egypt Andres (*3*) recorded it as being "cosmopolitan in stores." Specimens collected at Newton, Utah, in October 1933 were sent in by G. F. Knowlton with the report that they were very abundant in stored wheat. All the specimens in the lot were found to be *T. madens*.

MATERIALS INFESTED

The flour beetles are known to attack such a wide variety of foods that they can be said to be practically omnivorous. They have been found feeding in over 100 different foodstuffs. The list comprises mainly grain and seeds of various kinds, flour, meal, and other cereal products, but also includes animal matter, wood, vegetables, and various drugs and spices.

FLOUR

Flour is the material principally infested by *Tribolium*. Practically any kind of flour may be infested, and whole-wheat flour seems especially liable to attack. The flour beetles have been considered second to the Mediterranean flour moth in the damage done in flour mills but at present are undoubtedly the most abundant and injurious insects found in such situations. However, they are usually less of an annoyance than the moth to millers because they do not spin webs that clog up the pipes and machinery. Where these pests are present in numbers the flour becomes grayish and discolored and will mold more quickly than clean flour. Sometimes the disagreeable, pungent odor given off by the scent glands is imparted to the flour, giving it a disgusting taste and odor.

OTHER CEREAL PRODUCTS

Meal and many other ground products of grain are favored foods, and practically any kind of commercial breakfast food, stale bread, cakes, and cornstarch and other starches may be found to contain these pests. They often become very annoying in grocery stores, and if they become abundant they will get into every article of food in the place, sometimes almost ruining the merchant's business until he thoroughly fumigates the entire store. They are among the worst of pests on ships carrying edible produce of any kind because they will breed continuously and infest practically every foodstuff on board.

GRAIN AND OTHER SEEDS

The species of *Tribolium* cannot feed on entire, undamaged grain because their mandibles are not strong enough to chew through the tough outer coating. Practically all lots of grain, however, contain a certain percentage of broken kernels, so these beetles may be found infesing almost every known kind of grain. They are very common in grain shipments, usually occurring with either *Sitophilus* or *Rhizopertha*, at first more or less in the role of scavengers, but as the grain becomes more and more damaged they are able to do considerable injury of their own accord.

Grain waste and cracked grain products such as chicken feed are especially liable to attack. Quaintance reported corn in the field as attacked by *Tribolium castaneum*, but of this the writer is inclined to be very doubtful.

Excepting the grains, peas and beans of all kinds seem to be the seeds most commonly attacked. Cacao beans are often infested, and several instances of injury to cottonseed have been reported. There are many scattered references concerning injury to various seeds, and it seems likely that *Tribolium* will feed on practically any kind of seed, the only prerequisite being that some of the seeds be cracked or otherwise damaged.

NUTS

Although these insects are unable to penetrate the shells of most nuts, they will readily breed in any kind of cracked nuts and nut kernels. Persian (English) walnuts seem to be a favorite food, and peanuts are often infested and instances of serious damage to them have been reported (fig. 12, *A*).

DRIED FRUITS

Dried fruits of various kinds are often infested, but these flour beetles can hardly be said to be a major pest in such products. However, they occasionally do serious damage to raisins.

FOREST PRODUCTS

Since, as has already been shown, the original habitat of *Tribolium* appears to have been in rotting logs and under bark, it seems natural that all species of the genus should occasionally be found there at present. There are quite a number of references showing them to have been bred from various trees, especially from ash and pine. It seems probable, however, that they act as scavengers in such situations and do not feed on the wood itself. They have also been recorded from slippery elm and from resin, and the writer has observed that they sometimes riddle corks in the laboratory (fig. 13). Experiments on slippery elm and on cork indicate that they are unable to subsist on these products alone but use them only as auxiliary foods. It seems very unlikely that they could breed in resin.

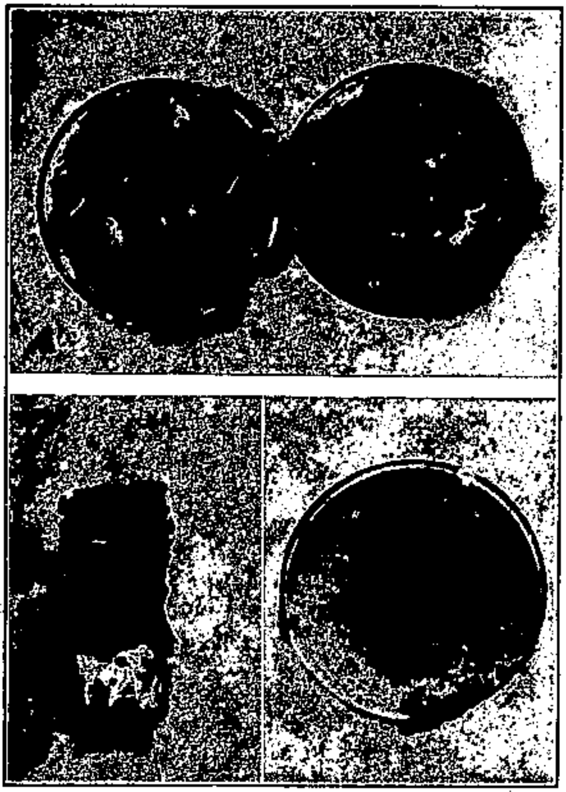

FIGURE 12.—Damage to foodstuffs by flour beetles: *A*, Peanuts infested by *Tribolium castaneum* following slight preliminary damage by *Plodia interpunctella*; *B*, adults of *T. confusum* feeding in a yeast cake.

SPICES

Several kinds of spices are attacked by the flour beetles. The writer was able to breed *T. confusum* in cayenne pepper with some difficulty and found that they would feed and survive for months on nutmeg and ginger. They have also been reported as feeding in mustard and cinnamon.

OTHER PLANT PRODUCTS

These beetles have been reported in snuff and orris root, and the writer's experiments indicate that they are able to breed in both of these products. Baking powder is an acceptable food. They will also survive for some time on brown sugar but will not breed in it.

The beetles have several times been reported as feeding on yams, garlic, and other vegetables, but there are no records of their having been bred from these products. Herbarium specimens frequently suffer from their attacks. There are a few records of feeding on cured tobacco and dried cornstalks, but there seems to be no danger that these beetles will become a pest in tobacco.

They seem to have a liking for milk chocolate and will readily breed in it. However, this commodity tends to become sticky during hot weather, especially in the presence of the beetles, and they easily become entangled and perish. The writer has observed them breeding in yeast cakes in large numbers (fig. 12, *B*). Although no other food but the yeast was available, the beetles were exceptionally large and active, indicating that yeast provides a very satisfactory food.

FIGURE 13.—A small cork riddled by *Tribolium confusum*, × 3.

ANIMAL MATTER

In insect collections *Tribolium* may do as much damage as the dermestids, and collectors must be continually on the lookout for their depredations. Although they cannot climb glass or smooth metal containers they can easily climb an insect pin, apparently by clutching the pin with their claws, and thus reach the mounted specimens. Hides and bird skins often become infested and ruined by these little pests. One record reports feeding on hog's bladder. Although not normally predacious, they have been observed to attack *Ephestia* larvae. However, it is doubtful whether this is of frequent occurrence, and experiments by the writer indicate that only the dying or diseased *Ephestia* larvae are subject to such attacks. Reports from India show that they also feed on lac. They have been found in the cells of bees in Hawaii but undoubtedly fed only on the pollen and did not otherwise molest the bees. Dried buttermilk and milk powder have been shown to be very satisfactory foods for these beetles.

LIFE HISTORY OF TRIBOLIUM CASTANEUM AND T. CONFUSUM

THE EGG

The eggs of *Tribolium confusum* (fig. 14) are oblong in shape, averaging 0.60 mm in length by 0.35 mm in width. The eggs of *T. castaneum* are indistinguishable from those of *T. confusum.* The eggs of both species are whitish or colorless and nearly transparent.

The shell is smooth, unmarked, rather thin and pliable, and is covered with a sticky substance that aids in attaching the eggs to surfaces and causes small particles to adhere to them. Thus, eggs which are laid in flour or other finely ground substances are almost invariably coated more or less thickly. This makes it very difficult to detect the eggs in flour.

The eggs are placed directly in the flour or other foodstuff in which the adult is living. They may lie free in the flour or be attached to the surface of the container. The adults have usually been said to lay their eggs in cracks and crevices, but observations indicate that they show little preference for such places, the presence of food being the main consideration, and the eggs are placed anywhere in the food material.

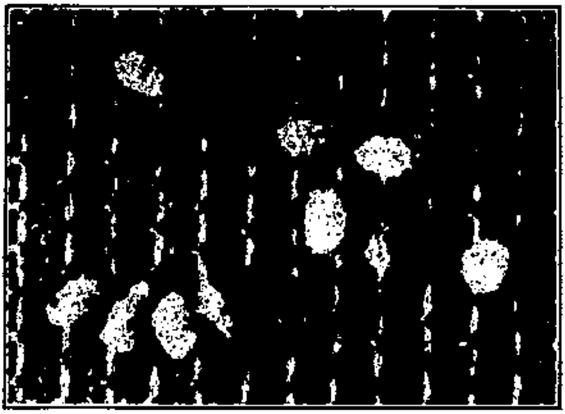

FIGURE 14.—Eggs of *Tribolium confusum* on no. 10 XX silk bolting cloth, × 16. (Dean.)

INCUBATION PERIOD

Since external conditions have a very marked influence on the incubation period of most eggs, various conditions of temperature, humidity, and light were experimented with in order that the duration of the egg stage under different conditions might be determined. The majority of these experiments were made with eggs of *T. castaneum*. Eggs of this species placed outdoors in November in Washington, D. C., at temperatures ranging upwards from only slightly above freezing all failed to hatch. Other eggs placed in a refrigerator at 6° C. failed to hatch. No constant temperatures between 6° and 25° were available so neither the killing point nor the minimum incubation temperature is known. Eggs kept at 35° likewise failed to hatch, while at 32° mortality was high but development rapid. Thirty degrees seems to be close to the optimum incubation temperature for eggs of this species. A lot of 137 eggs kept at this temperature hatched in from 3 to 5 days, with an average of 4 days. The records of some of these are shown in table 6. At 27° eggs hatched in a period averaging 5.2 days (table 3) and at 25° the period was from 5 to 7 days, averaging 6 days (table 5). Thirty-one eggs kept at room temperature in April required an average of 8.8 days to hatch (table 4). Here the temperature ranged from 18.5° to 28.5° and averaged 22° while the humidity ranged from 22 to 43 percent and averaged 32 percent. Twelve eggs kept at room conditions in November required 8 to 11 days with an average of 10 days. Here the temperature ranged from 18° to 29° and averaged 24°, while the relative humidity ranged from 27 to 47 percent and averaged 36 percent. All these experiments were carried on in continuous darkness to eliminate the variable factor of daylight. Continuous light slightly accelerates development.

The incubation period for *T. confusum* seems to be slightly longer than for *T. castaneum.* At 27° C. 37 eggs hatched in an average period of 6.8 days. The effect of light was tested in this case. Seventeen of these eggs were kept in continuous light and 20 were kept in continuous darkness. Those in continuous light had an average incubation period of 6.5 days, while those in continuous darkness required an average period of 7 days. An average of 12.8 days was required for the hatching of 40 eggs kept where the temperature averaged 21° and the relative humidity averaged 34 percent.

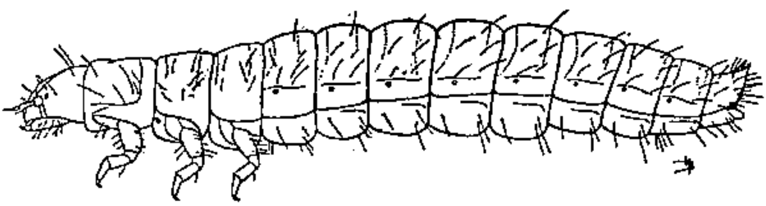

FIGURE 15.—*Tribolium castaneum:* Mature larva, × 20.

PERCENTAGE OF VIABLE EGGS

Records on the hatching of several hundred eggs show that under favorable conditions approximately 90 percent of the eggs laid by young females will hatch. Very old females may lay infertile eggs for considerable periods, sometimes months, before oviposition finally ceases.

THE LARVA

GENERAL DESCRIPTION OF MATURE LARVAE AND CHARACTERIZATION OF THE GENUS TRIBOLIUM MACL.[4]

Length, 6 to 7 mm; color mostly white, tinged with yellow, with dorsal part of head capsule, tips of claws, and terga of all segments slightly darkened, urogomphi and tips of mandibles testaceous. Form elongate cylindrical, about eight times as long as wide; dorsally convex, ventrally slightly flattened; ninth abdominal segment subquadrate in shape, bicornute; head and terga of all segments clothed with yellowish tactile hairs; body provided with a few long, thin, yellowish setae, those on ninth abdominal segment more numerous. Dorsal half of head capsule convex, not punctate, frontal angle not raised or produced. Ocelli, represented by two transverse groups of pigmented ophthalmic spots on each side of head, sometimes indistinct. Antennal articles with first slightly longer than wide; second about twice as long as wide, nearly twice as long as first article, distally bearing a minute supplementary appendix; third (apical article) small, elongate, cylindrical, about as long as first. Clypeus bearing two setae near each side margin. Labrum without transverse elevation or

[4] By R. A. St. George; based on larvae of *Tribolium castaneum* Hbst. and *T. confusum* J. du V. in the collection of the U. S. National Museum.

series of spines across median area, the latter provided with two prominent setae each side; along antero-lateral margin ventrically, three short spinelike setae. Mandibles of right and left sides differing in shape slightly; both apically bifid, each with an additional tooth along dorsal margin of cutting edge between apex and molar part; tooth of right mandible placed near apex, that of left near molar part; ventrally with cutting edge deeply excavated; exterior surface distally rounded, proximally slightly excavated, without membranous elevation and without tubercle near fossa; usually bearing three setae on dorsal side, one placed distally about midway between apex and fossa, one placed proximally near fossa, and the other usually placed about equidistant between them. Epipharynx with minute paired hooks on soft-skinned portion. Hypopharyngeal sclerome absent, region membranous. Prothoracic legs only slightly larger than mesothoracic and metathoracic pairs. Spiracles annular, with circular mouth piece. Ninth abdominal segment distinctly shorter than eighth wider than long; urogomphi directed upward and backward (not hoop shaped); side margins without short spinelike setae; ninth sternum bearing a few setae. Anal pseudopods distinct, quite long, cylindrical in shape.

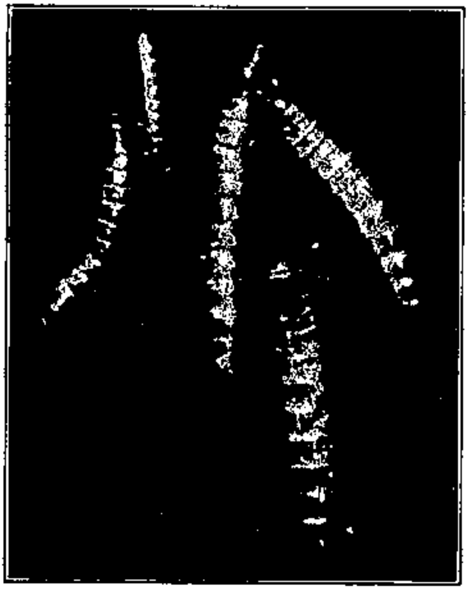

FIGURE 16.—Larvae of *Tribolium confusum*; The small one is a third-instar larva, the others are sixth-instar larvae, × 8.

FIELD IDENTIFICATION

The larvae of *Tribolium* may be readily distinguished from the somewhat similar appearing larvae of *Gnathocerus*, *Palorus*, or *Alphitobius* by the prominent two-pointed or forked termination of the last body segment (figs. 15 and 16). In each of the other genera mentioned, the body terminates caudally in a single point. In *Tenebrio* there is a small fork, somewhat intermediate between that of *Tribolium* and the single-pointed termination of *Gnathocerus*, etc.

NUMBER OF LARVAL INSTARS

Actual counts of the number of larval instars in *T. confusum* have previously been made by Chapman and by Brindley. Chapman (*17*) gives the idea that there are always 6 instars, but later shows that external conditions, especially food, may increase this number to as many as 12. In order to determine the exact number of larval instars, the writer placed eggs of both species of *Tribolium* in separate small vials and observed them each day until the individuals emerged as adults. One hundred and thirty individuals were thus observed. Various conditions of temperature, humidity, and food were covered in these tests. After each molt the exuviae were removed and recorded. Through these observations the writer has determined that there is no fixed number of larval instars, the number ranging from 5 to 11 or more, and that the usual number is 7 or 8 instead of 6. This variation is due to both external conditions, such as food, temperature, humidity, etc., and to individual characteristics entirely apart from external influence.

DURATION OF THE LARVAL INSTARS

Detailed results of the work on the life cycle of *Tribolium* are given in tables 2, 3, 4, 5, and 6. As shown in these tables, the larval period ranges from 22 to over 100 days, according to the temperature and food. The period for *T. confusum* is somewhat longer than for *T. castaneum.* The optimum temperature for the development appears to be 30° C. for both species. Growth is rapid in such foods as whole-wheat flour, middlings, bran, and corn meal, but very slow in white flour.

TABLE 2.—*Developmental data on Tribolium confusum at 27° C.*

Individual no.	Length of egg stage	Duration of larval instars [1]										Length of larval period	Length of pupal period	Length of developmental period	Sex	Kept in light (L) or darkness (D)	Food
		First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Last						
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*			
1	6	1½	4	4	5	5	5	------	------	------	7	31	8	45	Male	D	Middlings.
2	8	1½	4½	4	4	4	4	------	------	------	8	30	7	45	Female	D	Do.
3	8	1½	4½	4	4	4	4	5	------	------	5	32	7	47	do	D	Do.
4	6	2	5	4	4	5	5	------	------	------	6	31	9	46	Male	L	Do.
5	5	1½	4	5	4	5	6	------	------	------	8	33	8	46	do	D	Bran.
6	7	3	4	5	5	6	7	------	------	------	6	36	8	51	Female	D	Do.
7	8	2	5	5	4	5	5	------	------	------	9	35	9	52	do	D	Do.
8	6	2	4	5	5	6	6	6	------	------	6	40	8	54	do	D	Do.
9	7	3	5	6	5	6	5	4	------	------	6	40	9	56	do	D	Do.
10	7	2	6	5	5	9	8	------	------	------	8	43	9	59	do	L	Do.
11	8	4	4	5	6	6	6	6	------	------	7	44	9	61	do	D	Do.
12	8	1½	4½	8	7	8	10	7	------	------	7	53	9	70	do	D	Do.
13	7	2	13	7	7	7	5	5	------	------	9	55	10	72	Male	L	Do.
14	8	1½	8	14	13	5	5	5	------	------	9	60	9	77	Female	D	Do.
15	8	1½	5½	7	9	8	8	10	7	------	8	64	8	80	do	D	Do.
16	6	1½	5	8	8	6	7	8	------	------	9	52	8	66	Male	D	Oatmeal.
17	7	2	4	6	8	6	7	8	------	------	9	50	9	66	Female	L	Do.
18	5	1½	7	6	8	8	7	8	------	------	10	55	9	69	Male	D	Do.
19	8	3	8	6	8	7	8	8	------	------	11	59	9	76	do	L	Do.
20	7	2	5	8	9	13	[illegible]	10	8	8	7	107	6	120	do	L	Do.
21	8	1½	4½	6	7	8	18	25	------	------	19	89	8	105	do	D	White flour.
22	8	2	4	21	10	40	------	------	------	------	35	112	9	129	do	D	Do.
23	7	3	4	5	5	6	8	9	------	------	25	65	[2]	------	do	D	Do.
24	7	2	5	6	7	9	15	10	15	[2]	------	------	------	------	------	D	Do.
25	7	2	6	6	8	7	10	13	[2]	------	------	------	------	------	------	L	Do.
26	6	2	5	5	8	9	16	14	[2]	------	------	------	------	------	------	L	Do.
27	8	2	5	6	9	10	16	[2]	------	------	------	------	------	------	------	D	Do.
28	8	1½	5½	5	5	7	14	[2]	------	------	------	------	------	------	------	D	Do.

[1] The fractions are approximate, and the full larval periods have been rounded to whole days.

[2] Died.

TABLE 3.—*Developmental data on Tribolium castaneum at 27° C.*

Individual no.	Length of egg stage	Duration of larval instars										Length of larval period	Length of pupal period	Length of developmental period	Sex	Food
		First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Last					
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*		
1	5	2	4	4	3	3	----	----	----	----	6	22	7	34	Male	Middlings.
2	5	2	4	4	3	3	----	----	----	----	7	23	7	35	do	Do.
3	5	2	4	4	3	4	----	----	----	----	7	24	7	36	Female	Do.
4	5	2	4	4	5	5	5	----	----	----	8	33	7	45	do	Do.
5	5	2	5	5	4	5	6	7	----	----	6	40	8	53	Male	Do.
6	5	2	7	4	5	5	5	7	----	----	8	43	8	56	Female	Do.
7	5	2	6	5	5	5	6	6	----	----	8	43	8	56	do	Do.
8	6	2	4	3	4	4	----	----	----	----	7	24	7	37	Male	Bran.
9	5	2	4	4	4	4	----	----	----	----	8	26	7	38	do	Do.
10	5	2	4	4	4	4	----	----	----	----	8	26	7	38	do	Do.
11	5	2	4	4	4	4	5	----	----	----	5	28	8	41	Female	Do.
12	5	2	4	4	4	4	5	----	----	----	7	30	8	43	do	Do.
13	6	2	5	4	5	4	5	----	----	----	7	32	8	46	Male	Do.
14	6	2	6	5	4	5	5	----	----	----	9	36	8	50	Female	Do.
15	5	2	6	3	3	4	5	----	----	----	6	29	7	41	do	Whole-wheat flour.
16	6	2	4	4	4	4	4	----	----	----	6	28	7	41	Male	Do.
17	6	1	4	4	4	4	5	----	----	----	6	28	7	41	Female	Do.
18	6	2	4	4	3	4	5	----	----	----	6	28	8	42	Male	Do.
19	6	1	4	4	4	4	5	----	----	----	6	28	8	42	Female	Do.
20	5	2	4	4	4	5	4	----	----	----	7	30	8	43	Male	Do.
21	5	2	4	5	7	5	6	6	----	----	7	42	9	56	Female	Do.
22	5	2	4	4	3	4	----	----	----	----	8	25	7	37	Male	Corn meal.
23	5	2	4	4	3	4	----	----	----	----	8	25	7	37	Female	Do.
24	5	2	4	4	3	5	4	----	----	----	6	28	7	40	Male	Do.
25	5	2	4	4	4	4	5	----	----	----	7	30	8	43	do	Do.
26	6	2	4	4	5	4	4	----	----	----	7	30	7	43	Female	Do.
27	6	2	5	5	4	5	----	----	----	----	8	29	8	43	Male	Do.
28	5	2	6	6	4	4	5	----	----	----	8	35	8	48	Female	Do.
29	6	2	6	9	6	6	7	10	----	----	7	53	7	66	Male	Do.
30	5	2	6	6	6	6	7	6	9	----	6	54	7	66	do	Oatmeal.
31	5	2	5	4	4	10	7	12	----	----	18	62	6	73	do	Do.
32	5	2	5	7	10	10	14	13	----	----	6	67	6	78	Female	Do.
33	5	1	6	8	10	15	12	9	9	11	9	90	7	102	Male	Do.
34	5	2	6	7	8	6	6	7	12	(1)	----	----	----	----	----	Do.
35	5	2	6	17	17	15	10	10	10	(1)	----	----	----	----	----	Do.
36	5	2	5	6	7	12	22	(1)	----	----	----	----	----	----	----	White flour.
37	5	2	5	5	10	20	----	----	----	----	31	73	7	85	Male	Do.
38	5	2	5	5	8	11	15	17	26	----	14	103	6	114	do	Do.
39	5	2	6	6	6	13	19	(1)	----	----	----	----	----	----	----	Do.
40	5	2	6	8	8	11	(1)	----	----	----	----	----	----	----	----	Do.
41	5	2	5	5	8	28	(1)	----	----	----	----	----	----	----	----	Do.
42	5	2	6	6	18	25	(1)	----	----	----	----	----	----	----	----	Do.
43	5	2	6	6	8	(1)	----	----	----	----	----	----	----	----	----	Do.

[1] Dead.

TABLE 4.—*Data on development of Tribolium castaneum at room temperatures in Washington, D. C., in 1930*

Individual no.	Date egg laid	Date egg hatched	Incubation period	Date of first molt	Length of first instar	Date of second molt	Length of second instar	Date of third molt	Length of third instar	Date of fourth molt	Length of fourth instar	Date of fifth molt	Length of fifth instar	Date of sixth molt	Length of sixth instar	Date of seventh molt
			Days		*Days*		*Days*		*Days*		*Days*		*Days*		*Days*	
1	Apr. 1	Apr. 10	9	Apr. 12	2	Apr. 20	8	Apr. 27	7	May 2	5	May 7	5	May 13	6	
2	do	do	9	Apr. 13	3	do	7	do	7	do	5	do	5	do	6	
3	do	do	9	do	3	Apr. 23	10	Apr. 29	6	May 4	5	May 9	5	May 14	5	
4	Apr. 2	Apr. 11	9	Apr. 14	3	Apr. 26	12	May 2	6	May 8	6	May 14	6	May 21	7	June 1
5	do	do	9	Apr. 13	2	Apr. 21	8	Apr. 27	6	May 2	5	May 6	4	May 10	4	
6	do	do	9	do	2	Apr. 20	7	Apr. 26	6	May 1	5	do	5	----------	----------	
7	do	do	9	do	2	Apr. 21	8	Apr. 27	6	May 2	5	May 7	5	May 12	5	
8	do	do	9	do	2	do	8	Apr. 28	7	do	4	May 6	4	May 14	8	
9	do	do	9	do	2	Apr. 22	9	Apr. 29	7	May 4	5	May 9	5	May 15	6	May 23
10	do	do	9	Apr. 14	3	Apr. 23	9	Apr. 30	7	May 5	5	do	4	May 13	4	May 21
11	do	do	9	Apr. 13	2	Apr. 22	9	do	8	May 6	6	May 11	5	May 20	9	June 3
12	do	do	9	do	2	Apr. 24	11	May 6	12	May 13	7	May 23	10	June 3	11	June 11
13	do	do	9	do	2	do	11	Apr. 30	6	May 5	5	May 11	6	May 17	6	May 26
14	do	do	9	do	2	Apr. 25	12	May 3	8	May 9	6	May 17	8	May 26	9	June 3
15	Apr. 3	do	8	Apr. 14	3	Apr. 29	15	May 7	8	May 14	7	May 22	8	June 2	11	June 8
16	do	Apr. 12	9	Apr. 15	3	Apr. 27	12	May 6	9	do	8	do	8	June 1	10	Do.
17	Apr. 2	do	10	Apr. 16	4	Apr. 22	6	Apr. 29	7	May 4	5	May 9	5	May 17	8	
18	Apr. 3	Apr. 11	8	Apr. 13	2	Apr. 21	8	Apr. 27	6	May 2	5	May 6	4	----------	----------	
19	do	do	8	Apr. 14	3	do	7	do	6	do	5	May 7	5	May 14	7	
20	do	do	8	do	3	Apr. 22	8	Apr. 28	6	May 3	5	May 8	5	----------	----------	
21	do	Apr. 12	9	do	2	Apr. 21	7	Apr. 27	6	May 1	4	May 5	4	----------	----------	
22	do	do	9	do	2	do	7	do	6	May 2	5	May 6	4	----------	----------	
23	do	do	9	do	2	do	7	do	6	do	5	May 7	5	May 12	5	
24	do	do	9	do	2	Apr. 23	9	Apr. 29	6	May 4	5	May 9	5	May 14	5	May 24
25	Apr. 4	do	8	do	2	do	9	May 2	9	May 9	7	May 20	11	June 3	14	June 14
26	do	do	8	Apr. 15	3	Apr. 25	10	May 4	9	May 13	9	May 28	15	June 11	14	June 18
27	do	Apr. 13	9	Apr. 16	3	Apr. 27	11	May 15	18	June 2	18	June 14	12	June 22	8	June 20
28	do	Apr. 12	8	Apr. 14	2	Apr. 22	8	Apr. 29	7	May 7	8	May 28	21	June 21	21	July 3
29	do	do	8	Apr. 15	3	Apr. 24	9	May 5	11	May 30	25	June 25	26	July 22	27	
30	do	Apr. 13	9	do	2	Apr. 23	8	May 2	9	May 11	9	June 5	25	June 24	19	
31	do	do	9	do	2	Apr. 21	9	May 5	11	May 20	15	June 3	14	June 15	12	June 29

Individual no.	Length of seventh instar	Date of eighth molt	Length of eighth instar	Date of ninth molt	Length of ninth instar	Date of tenth molt	Length of tenth instar	Date of pupation	Length of last instar	Length of larval period	Date adult emerged	Length of pupal period	Length of developmental period	Food	Sex
	Days		*Days*		*Days*		*Days*		*Days*	*Days*		*Days*	*Days*		
1								May 24	11	44	June 5	12	65	Bran	Male.
2								May 28	15	48	June 7	10	67	do	Female.
3								May 27	13	47	do	11	67	do	Do.
4	11	June 7	6					June 18	11	68	June 26	8	85	do	Male.
5								May 22	12	41	June 3	12	62	Whole-wheat flour	Do.
6								do	16	41	do	12	62	do	Female.
7								May 24	12	43	June 5	12	64	do	Male.
8								May 20	15	48	June 8	10	67	do	Female.
9	8							June 5	13	55	June 14	9	73	do	Do.
10	8							June 3	13	53	June 11	8	70	do	Do.
11	14							June 18	15	68	June 25	7	84	Corn meal	Male.
12	8							do	7	68	do	7	84	do	Female.
13	9							June 12	17	62	June 19	7	78	do	Do.
14	8							June 11	8	61	do	8	78	do	Male.
15	6	June 14	6					June 23	9	73	June 29	6	87	do	Female.
16	7							June 19	11	68	June 25	6	83	do	Do.
17								June 5	19	54	June 1[illegible]	9	73	do	Male.
18								May 15	9	34	May 27	12	54	Middlings	Do.
19								June 1	18	51	June 9	8	67	do	Do.
20								May 19	11	38	June 1	13	59	do	Female.
21								May 12	7	30	May 23	11	50	do	Do.
22								May 15	9	33	May 26	11	53	do	Male.
23								May 23	11	41	June 4	12	62	do	Do.
24	10							June 7	14	56	June 15	8	73	do	Female.
25	11	June 21	10	July 7	13	July 21	14	Aug. 20	30	130				Oatmeal	Male.
26	7	June 26	8	July 4	8	July 14	10	July 23	9	102	July 28	5	115	do	Do.
27	7	July 5	6	July 12	7	July 23	11	Aug. 1	9	110	Aug. 6	5	124	do	Do.
28	12	July 26	23	Aug. 2	(1)									White flour	
29								Aug. 5	14	115	Aug. 10	5	128	do	Female.
30								July 10	16	88	July 18	8	105	do	Male.
31	14	July 18	19					Aug. 7	20	116	Aug. 13	6	131	do	Female.

[1] Dead.

TABLE 5.—*Data on developmental period of Tribolium castaneum at 25° C. in whole-wheat flour*

Individual no.	Length of egg stage	Duration of larval instars [1]									Length of larval period	Length of pupal period	Length of period from egg to adult	Sex
		First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Last				
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	
1	7	2	6	4	6	5	7	-----	-----	8	38	8	53	Male.
2	7	1¾	6	4¼	5	6	8	-----	-----	11	42	8	57	Female.
3	5	2	7	3	5	5	10	-----	-----	12	44	10	59	Do.
4	5	2	6¾	3¼	6	6	8¼	-----	-----	13	45	9	59	Do.
5	7	1¼	6	4	6	6	7	-----	-----	12	42	13	62	Do.
6	6	2	5¾	4½	7	5	8	8	5	9	54	6	66	Do.
7	6	2	6	4	5	6	10	9	-----	11	53	7	66	Male.
8	6	2	8	4¼	7	6	6	7	5	9	54	6	66	Do.
9	6	1½	6	4	7	5	8	7	-----	15	53	7	66	Do.
10	6	2	7½	4½	6	7	8	8	-----	12	55	6	67	Do.
11	6	2	7	5	5	7	9	-----	-----	26	61	9	76	Female.

[1] The fractions are approximate, and the full larval periods have been rounded to whole days.

TABLE 6.—*Data on development of Tribolium castaneum at 30° C.*

Individual no.	Length of egg stage	Duration of larval instars [1]												Length of larval period	Length of pupal period	Length of developmental period	Sex	Food
		First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	Last					
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*		
1	4	2	2	4½	1¾	4	4						4	22	5½	32	Female	Corn meal.
2	4	1	5	4	2½	3½	3						3	22	5½	32	do	Do.
3	4	1	5¾	3	3	3	3						5	24	4	32	do	Do.
4	4	1	5¼	3½	2½	2½	5¾						4½	25	4	33	Male	Do.
5	4	1	5	2¾	4	3	3¾						8½	28	4½	36	do	Precooked wheat cereal.
6	4	1	6¾	4½	1¾	3¼	3¼	8½	15¼	11	11	31	[2] 16					Do.
7	4	2	6	4½	2¼	3½	5	6	11¼	19	18	[3] 19						Do.
8	4	2	4	3	4	3	5	12	[4] 14									Do.
9	4	1	6½	5	3¾	7	5½	[4] 8½										Do.
10	4	1½	6¼	5¼	2¾	3	4						5	28	4	36	Male	Dog biscuit.
11	4	1	7½	3½	1½	2	3	3					4	26	4½	34	do	Do.
12	5½	2	4½	7¼	3½	2¼							6	26	6	37	do	Do.
13	4	1½	5¾	4½	3¾	3¾	5	11					14	49	6	59	do	Pancake flour.
14	4	2	5	5¼	4	3½	5	11					16	52	6	62	do	Do.
15	4	1	7¾	4	4	3	5	8	10	5			5	53	6	63	do	Do.
16	4	1	5	5½	3¾	3	3¾	12	11	9			9	63	4	71	Female	Do.
17	4	2	6	5	4	4½	5	10½	11	7			12	67	6	77	do	Do.
18	4	1¾	5½	4¼	3¾	4	7¾	11	7	9	10		14	78	6	88	do	Do.
19	4	1	6¾	9	3	5	[illegible]	9¾	7½	11	13	16	7	97	6	107	do	Do.
20	4	1½	9	4¼	[5] 7¼													Red pepper.
21	4½	1½	6¼	5¾	[5] 4													Do.
22	4	1¾	4¼	4½	2½	3	4						6	26	4	34	Male	Oatmeal.
23	4	1¾	5¾	4¼	3	3							8	26	4	34	do	Do.
24	4	1½	5½	4	2¾	2¾	4¼						8	29	4	37	Female	Do.
25	4½	1¾	5	4	3	3¾							17	35	5	44	Male	Do.
26	4	1½	14½	4¾	3	6	6	7	10				13	66	6	76	Female	Do.
27	4½	1½	5¾	4¼	8	17	25	10	8	14	10	[6] 19						Do.
28	4½	1½	5¾	7	3	4	8	4					7	40	5	50	Female	Rye flour.
29	4	1¾	5	8	4	6							47	72	5	81	Male	Do.
30	4	1¾	5	4¼	3½	4¼	[3] 6											Do.
31	4	1½	3¾	5¾	6								5	22	4	30	Male	Whole-wheat flour.
32	4	1½	3½	4½	6	4							3	22	4	30	do	Do.
33	4	1½	4¼	3½	6								7	22	6	32	Female	Do.
34	5	1½	4¼	3¼	2¾	3¾	3						6	24	5	34	do	Do.
35	5	1½	4	3½	3¾	3	3						5	24	5	34	do	Do.
36	4	1½	5½	2½	4¼	3¼	4						6	27	5	36	Male	Do.

[1] The fractions are approximate, and the full larval periods have been rounded to whole days.
[2] Died Mar. 10.
[3] Died Feb. 11.
[4] Died Jan. 6.
[5] Died Dec. 3.
[6] Dead Mar. 12.

WIDTH OF THE HEAD CAPSULE

It was found possible to determine accurately the instar of a larva by measuring the width of the head capsule. There is considerable individual variation but practically no overlapping of the measurements of an individual of one stage with those of the next until after the sixth instar. The figures for *T. confusum* in table 7 will be found to differ from those of Chapman (*17*) and Brindley (*13*), both of whom based their data on larvae which completed their development in six instars.

TABLE 7.—*Measurements of Tribolium confusum*

Stage	Instar	Specimens measured	Body						Head capsule width			
			Length			Width						
			Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Increase
		Number	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*	*Mm*
Egg		40	0.600	0.476	0.601	0.400	0.257	0.355				
Larva	First	50	1.260	.863	1.113	.268	.193	.236	0.196	0.150	0.175	
Do	Second	45	1.828	1.220	1.490	.298	.223	.254	.213	.178	.197	0.022
Do	Third	34	2.514	1.607	1.918	.387	.268	.308	.268	.236	.249	.052
Do	Fourth	30	3.182	1.886	2.379	.447	.327	.368	.357	.277	.311	.062
Do	Fifth	22	3.818	2.273	3.044	.536	.417	.456	.420	.327	.378	.067
Do	Sixth	21	4.364	3.000	3.496	.658	.417	.524	.568	.417	.459	.081
Do	Seventh	13	5.091	4.091	4.643	.833	.655	.715	.655	.470	.585	.126
Do	Eighth	5	6.303	4.364	5.153	.953	.655	.846	.685	.536	.619	.034
Do	Ninth	3	5.818	5.363	5.545	.953	.804	.893	.714	.565	.655	.036
Pupa		18	3.818	3.000	3.369	1.280	1.012	1.132	.863	.729	.705	
Adult		10	3.820	3.090	3.475	1.260	1.080	1.169	.800	.700	.743	

HABITS

The larvae of *Tribolium* are fairly active and may be found in any of the foods listed under the heading Materials Infested. They usually shun the light and live more or less concealed in the food, in which they bury themselves if disturbed. In flour mills and warehouses they may often be found in cracks and in dark places, but more often they live directly in a quantity of flour or meal, feeding near the surface or under any piece of paper, wood, or other material that may be placed on the surface.

THE PUPA

PUPATION

When fully grown, the larva comes to the surface of the material in which it has been feeding, or to some sheltered space or crack, and there the change to the pupa takes place. As with many Coleoptera, the pupa of *Tribolium* is naked and without protection of any kind (figs. 17 and 18). Vacated pupal cells of the Mediterranean flour moth are favorite places for pupation when they are available, several *Tribolium* pupae often being found in one cell. At first the pupa is entirely white, but within a day or two it acquires a yellowish tint which gradually turns darker. Likewise, the eyes soon turn black, and the claws and the tips of the mandibles and of the urogomphi turn to a dark brown.

APPEARANCE OF THE PUPA

The eyes in *T. confusum* are nearly, but not completely, divided by the genae, while those in *T. castaneum* are only slightly emarginated. In both species the antennae, elytra, and legs are free but closely pressed against the body, the tips of the elytra reaching the middle of the fifth abdominal segment. The prothorax is rather thickly covered with short, stiff spines arising from tubercles. The front and side margins of the prothorax are fringed with setae; those along the side margins and the sides of the front margin are long, those near the center of the front margin much shorter.

The abdominal segments, excepting the eighth, ninth, and tenth, are provided laterally with characteristic irregular projections. In *T. confusum* these lateral processes are provided with 3 hairs, 1 rather long hair arising from the anterior lobe and 2 shorter hairs from very small median lobes. In *T. castaneum* 1 hair arises from the large anterior lobe and a shorter hair at a point one-third from the posterior serrate margin. The ninth segment is provided with 2 rather long urogomphi.

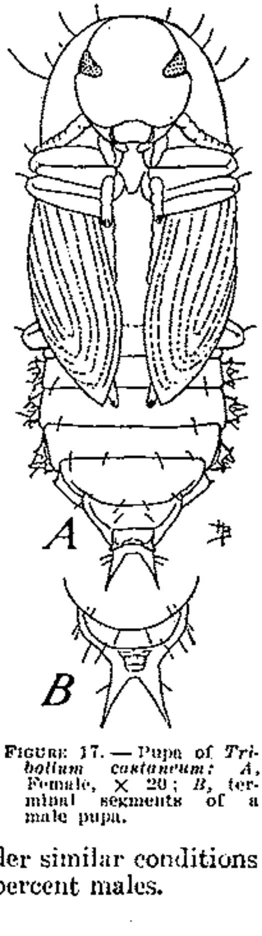

FIGURE 17.—Pupa of *Tribolium castaneum*: *A*, Female, × 20; *B*, terminal segments of a male pupa.

DIFFERENCE IN APPEARANCE BETWEEN MALES AND FEMALES

The appearance of the ventral surface of the terminal abdominal segment of the pupa differs greatly in the males and females. It is on this difference only that the sexes may be distinguished externally, since the appearance of the two sexes in the adult is identical. The form of the genital segment is shown in figure 17, *B*. The chief characteristic of this segment in the male is a flat disklike depression, whereas in the female two conelike appendages, similar in appearance to the urogomphi, but much shorter and relatively thicker, may be distinguished.

SEX RATIO

Of 800 individuals of *T. confusum* reared on whole-wheat flour at 30° C., 52 percent were females and 48 percent were males. Two hundred pupae of *T. castaneum* reared under similar conditions gave a sex ratio of 59 percent females and 41 percent males.

SIZE AND WEIGHT OF PUPAE

Measurements for *T. confusum* are given in table 7. Sixty pupae of *T. castaneum* averaged 3.35 mm in length, not including the urogomphi, and 1.17 mm in width through the elytra. Females averaged slightly larger than males. The head capsule widths of 35 individuals averaged 0.707 mm.

Six hundred and fifty pupae of *T. confusum* were weighed on an anylitical balance in lots of 50. Three hundred male pupae averaged

2.13 mg each and 350 female pupae averaged 2.49 mg each. There appeared to be only slight variation in the size and weight of individuals. Of 125 pupae of *T. castaneum*, 53 males averaged 1.77 mg each, while 72 females averaged 1.89 mg each.

PUPAL PERIOD

The duration of the pupal period seems to be less affected by external conditions than that of the egg or larval periods. Records on the pupal period are given in tables 2, 3, 4, 5, and 6. Quite a few additional pupal records were obtained, and the summary of all pupae observed is as follows:

FIGURE 18.—Pupae of *Tribolium confusum*, × 7½.

Of pupae of *T. confusum* kept at 27° C., 31 kept in continuous darkness emerged as adults in from 7 to 12 days, with an average of 8.7 days; and 43 kept in continuous light emerged in from 6 to 9 days, with an average of 7.9 days. One hundred and twelve pupae of *T. castaneum* kept at 27°, for the most part in continuous darkness, had a pupal period of from 6 to 9 days, with an average of 7.14 days; and 28 kept at 30° emerged in from 4 to 6 days with an average of 5 days. Eleven kept at 25° emerged in from 6 to 12 days with an average of 8.8 days, and 32 kept at room temperature during the early summer had a period ranging from 5 to 14 days, averaging 8.5 days.

THE ADULT

Adults of both these species of *Tribolium* are small, reddish-brown beetles, about 3.5 mm in length, and with the elytra striated (figs. 2, 3, and 19). Superficially the two species are very much alike, but with the aid of a microscope the differences in the eyes and antennae readily separate them. In each species the sexes are identical externally and cannot be differentiated except by squeezing out the genitalia by a slight pressure on the abdomen.

FLIGHT

Both species have well-developed wings, but only *T. castaneum* has been observed to use them. This species is not a strong flier and flies only occasionally. In the laboratory the longest period during which it remained on the wing was approximately 20 seconds, but it seems probable that in the open it could stay in the air for somewhat longer periods. It could not fly from one flour mill to another unless the mills were very close together and the flight were aided by wind, but it could possibly fly from the hold of a ship to a pier. It has been seen to fly so seldom, however, it appears unlikely that an infestation would spread often in this manner. *T. confusum*, although possessing well-developed wings, has never been taken in flight, and attempts to induce it to fly have always failed.

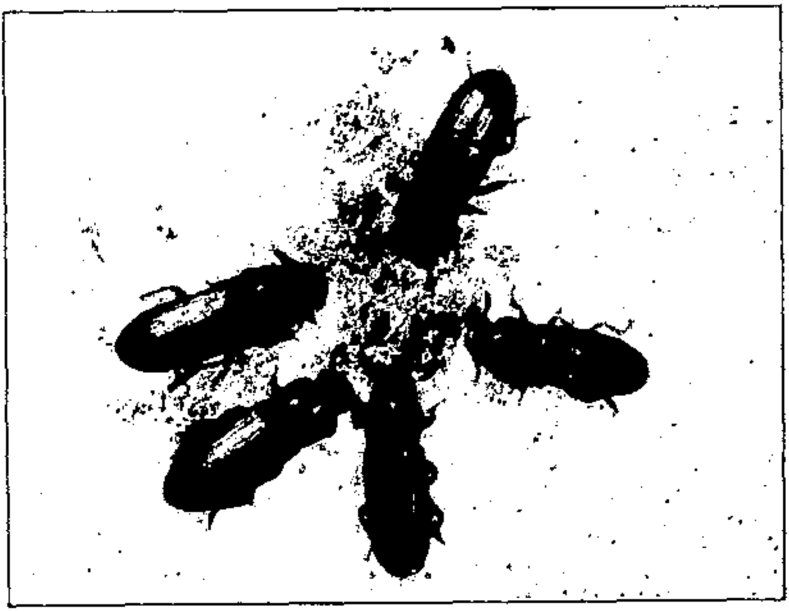

FIGURE 19.—Adults of *Tribolium confusum* feeding on flour, × 8½.

ACTIVITY

Adult flour beetles are rather active, quickly running to cover or burying themselves in the flour if disturbed. Ordinarily they live concealed in the flour or under any suitable object which may be near their food supply. They do not always try to hide themselves, however, and numbers may usually be found crawling around over flour or grain in mills or stores (fig. 19). They move about readily inside a building and soon infest every article of food in the place. Their small size and flat bodies enable them to force their way into all but the tightest boxes or containers.

EFFECT ON FLOUR

Light infestations of flour beetles usually would pass unnoticed except for the beetles themselves, as they seem to do less perceptible damage to their foodstuff than do most insects. But if the beetles are present in quantities, a certain discoloring of the flour takes place, and in time it turns to a dirty grayish mass.

SCENT GLANDS

The scent glands of these beetles are rather well developed and contain a vile-smelling fluid which is ejected as a means of defense, often imparting a disagreeable, pungent odor to the food. It is often released when the beetles are excited by the stirring up of the flour in which they are feeding, or when a beetle is crushed between the fingers. Functional scent glands are possessed by the adults of both species but not by the larvae.

SEASONAL HISTORY

Since the flour beetles nearly always live in protected situations, and often in buildings heated the year round, there is no very marked seasonal variation in their activity. When they are exposed to cold weather for long periods their activities are retarded, and those in the less resistant stages of their life cycle may succumb. It may also be noted that in very hot climates the insect's activities are speeded up, and life is much shorter than in cool climates. In heated flour mills and warehouses *Tribolium* breeds the year round, and all stages may be found at any time. In unheated mills this is not the case. Some authors have stated that these beetles do not live over the winter in unheated mills but die out with the coming of cold weather; and the mills are reinfested in the spring from neighboring heated mills. Inspection of several unheated mills in Maryland and northern Virginia during February revealed many adults of *T. confusum* in a semidormant condition, but no living larvae or pupae. As the adults may live over a year it is evident that in unheated mills in this area the winter is passed in the adult stage, and breeding begins with the approach of spring. In the Gulf States breeding probably continues throughout the year, while in the extreme northern States and Canada the species may not be able to survive the winter except in heated buildings. *T. castaneum* seems to be less resistant to cold than *T. confusum*.

LONGEVITY

The developmental stages of *Tribolium* are comparatively short, but the adult life is among the longest recorded for the stored-product insects. Previous estimates of the adult life have ranged from 3 months to a year, but the writer's observations on 25 pairs each of *T. confusum* and *T. castaneum*, which were used in oviposition experiments, and results from an experiment run for this specific purpose show that the maximum length of adult life may be over 3 years.

Early in 1930 an experiment was started in which 50 adults of *T. confusum* of known sex and usually of known parentage were segregated on emergence and examined periodically to determine the maximum length of life for this species. The beetles were put into 16 by 50 mm vials, lightly stoppered with cotton, and kept in darkened pasteboard boxes at room temperature. A variety of different foods was used. The numbers of these individuals decreased gradually, the mortality being somewhat greater during July and August of each year, owing, no doubt, to the excessive heat. The data on seven of these individuals that survived for more than 2 years and 11 months are given in table 8.

TABLE 8.—*Some examples of extreme adult longevity in Tribolium confusum, Washington, D. C.*

Individual no.	Sex	Food	Date adult emerged	Date adult died	Adult age at death
			1930	1933	
1	Male	Whole-wheat flour	Jan. 27	Mar. 14	3 years, 46 days.
2	do	do	Feb. 7	Nov. 5	3 years, 271 days.
3	Female	do	Feb. 10	May 20	3 years, 99 days.
4	Male	do	Mar. 16	Apr. 5	3 years, 20 days.
5	Female	Oatmeal	Mar. 17	Apr. 3	3 years, 17 days.
6	do	Whole-wheat flour	Mar. 25	Mar. 7	2 years, 347 days.
7	Male	Oatmeal	May 10	Aug. 28	3 years, 110 days.

All the adults used in oviposition experiments were likewise segregated and examined periodically to determine the length of life of each. These were kept in smaller vials (11 by 40 mm) and under various conditions. Of the 25 pairs each of *T. confusum* and *T. castaneum*, 14 individuals survived for more than 2 years as shown in table 9.

TABLE 9.—*Adult life of 14 individuals of Tribolium, Washington, D. C.*

Tribolium confusum			*Tribolium castaneum*		
Pair no.	Sex	Adult life	Pair no.	Sex	Adult life
25	Male	3 years, 208 days	15	Male	2 years, 159 days.
21	do	2 years, 327 days	8	do	2 years, 154 days.
23	Female	2 years, 217 days	17	do	2 years, 86 days.
22	do	2 years, 212 days	9	do	2 years, 77 days.
13	Male	2 years, 189 days			
23	do	2 years, 169 days			
24	do	2 years, 153 days			
15	do	2 years, 96 days			
14	do	2 years, 69 days			
21	Female	2 years, 26 days			

It should be mentioned that each female in this case laid several hundred eggs, while those given in table 8 never mated. It is also interesting to note that all the individuals in the oviposition experiment that survived more than 2 years were fed on whole-wheat flour, although five other foods were used in the experiments. From these tables and other data it seems that *T. confusum* live somewhat longer than *T. castaneum* and likewise that males live somewhat longer than females.

From the life-history data of tables 10 and 11 it may be found that the average adult life of males of *T. confusum* is about 634 days, and of females, 447 days. For *T. castaneum* the average for males is 547 days, and for females, 226 days.

FERTILITY OF VERY OLD BEETLES

Experiments have proved not only that these beetles live to a comparatively great age but that males of *T. confusum* may be fertile even when they are 3 years or more of age. Male no. 2 was twice placed with virgin females, first at the age of 3 years, 64 days, and again at 3 years, 76 days; while male no. 7 was mated with a virgin female when the former was exactly 3 years of age. In all these cases normal offspring were produced. Females, however, have never laid fertile eggs when more than 1 year and 94 days old.

RESISTANCE TO STARVATION

The length of time flour beetles can live with no food whatever is greatly influenced by the temperature, resistance to starvation increasing inversely with the temperature. Also a relative humidity of about 60 percent is more favorable for survival than one of 30 percent or less. Several experiments on starvation were made by placing adults or larvae of known age in individual vials with no food and keeping them at the desired temperature and humidity. These were examined daily until the last individual had died.

Adults of the two species seemed equally resistant to starvation. At 30° C. adults will survive for about 2 weeks, the longest period any of 25 individuals of both species survived being 18 days. At ordinary room temperatures during the winter the longest period recorded was 23 days; at 15° some survived for 27 days, at 10° several individuals lived over 40 days, and one adult, *T. confusum*, for 51 days. Larvae seem to be slightly more resistant to starvation than adults. At 30° the longest period recorded for a larva was 23 days. At ordinary room conditions in winter one individual survived 46 days, and at 15° the last larva was not dead until the fifty-fourth day.

Larvae without food will molt and change to pupae and adults nearly as readily as those with food. Those individuals that changed to adults during the experiments lived as long as, and sometimes longer than, those that remained in the larval stage.

MATING

Among pairs kept under observation mating occurred rather frequently. It usually began within a day or two after emergence and probably continued at frequent intervals throughout life. Frequent mating is not necessary for the production of fertile eggs. In certain instances females have been known to continue laying viable eggs for a period of 5 months after being segregated from males.

OVIPOSITION

The study of oviposition in *Tribolium* seems to have received very little attention. However, when it is considered that the oviposition period may last more than a year and that it is almost impossible to locate the eggs in the flour, it is not surprising that more work has not been done along this line. In the experiments made by the writer 25 pairs of each species were segregated on emergence and placed in different foods and under different conditions of temperature and humidity. Small vials, lightly stoppered with cotton, were used as containers. A pair of adults was placed in each vial and changed to another vial every day. Various methods of locating the eggs were tried, but it was found that the method, first advocated by Chapman (*17*), of counting the larvae rather than the eggs was more accurate. It was found by an actual count of both the eggs and the resulting larvae, that approximately 90 percent of the eggs of young females were viable. As the females increased in age the percentage of viable eggs gradually decreased. Thus the actual number of eggs laid is at least one-ninth greater than indicated by the figures given in tables 10 and 11, which represent only the eggs that hatched.

PREOVIPOSITION PERIOD

The length of the preoviposition period may range from 4 to an indefinite number of days, depending on the temperature. Mated females of either species placed in the incubator at 27° C. usually began to lay viable eggs within 1 week after emergence. Adults emerging late in the spring or in the summer likewise began to oviposit within a few days. Those adults which emerged during the winter, however, and were kept at room conditions usually did not begin ovipositing until the approach of warm weather late in March or in April.

DURATION OF OVIPOSITION PERIOD

The flour beetles have a very long oviposition period. The average period for a number of females of *T. castaneum* in laboratory tests was 148 days at 27° C. and 174 days at ordinary room temperatures. For *T. confusum* the average oviposition period at 27° was 235 days and at room conditions 277 days. The longest oviposition periods recorded are 308 days for *T. castaneum* and 432 days for *T. confusum*. Both of these individuals were kept under ordinary room conditions.

RATE OF OVIPOSITION

In no case were more than 13 viable eggs laid in 1 day by a single female, and the average was only 2 or 3 per day. Under optimum conditions Brindley (*12*) records 18 viable eggs in 1 day and a much higher daily average than indicated by the author's records.

NUMBER OF EGGS LAID

The total number of eggs laid seems to depend mainly upon the food. Under the various conditions of temperature and food of the oviposition tests the average number of viable eggs laid by individual females of *T. castaneum* was 327 and of *T. confusum* 458. The greatest number of viable eggs laid by *T. castaneum* was 956, while 976 was the greatest number laid by *T. confusum*.

Tables 10 and 11 give data on the oviposition and longevity of the two species.

Table 10.—*Data concerning oviposition and longevity of Tribolium castaneum*

Pair no.	Date male emerged	Date female emerged	Date mated	Date first viable egg laid	Length of preoviposition period	Date last viable egg laid	Length of oviposition period	Total viable eggs laid	Average viable eggs laid per day	Date male died	Date female died	Length of postoviposition period [1]	Longevity of male	Longevity of female	Temperature	Food
	1930	1930	1930	1930	*Days*	1930	*Days*	*Number*	*Number*			*Days*	*Days*	*Days*	° *C.*	
1	([2])	([2])	Jan. 27	Feb. 5	------	June 4	119	149	1.25	Nov. 14, 1930	June 12, 1930	8	------	------	27	Bran.
2	Feb. 8	Feb. 8	Feb. 13	Feb. 17	9	Aug. 23	187	283	1.51	Feb. 12, 1931	Sept. 6, 1930	14	369	210	27	Do.
3	do	do	do	Feb. 15	7	July 1	136	273	2.01	Feb. 6, 1931	July 2, 1930	1	363	144	27	Do.
4	Feb. 9	do	do	Feb. 18	10	Sept. 9	203	643	3.17	Nov. 3, 1931	Sept. 23, 1930	14	632	227	27	Whole-wheat flour.
5	do	Feb. 9	do	Feb. 17	8	Oct. 7	232	572	2.47	Mar. 12, 1931	Oct. 8, 1930	1	396	241	27	Do.
6	Feb. 8	Feb. 8	do	Feb. 14	6	July 30	166	593	3.57	Dec. 20, 1931	July 30, 1930	0	680	172	27	Do.
7	Feb. 9	Feb. 9	do	Feb. 21	12	July 11	140	438	3.13	June 23, 1931	July 21, 1930	10	499	162	27	Do.
8	do	do	do	Feb. 17	8	June 28	131	178	1.36	July 12, 1932	July 11, 1930	13	884	152	27	Do.
9	do	do	do	Feb. 20	11	July 21	151	206	1.36	Apr. 26, 1932	July 22, 1930	1	807	163	27	Do.
10	do	do	do	Feb. 18	9	July 17	149	477	3.20	Feb. 16, 1931	July 30, 1930	13	372	171	27	Middlings.
11	do	do	do	Feb. 15	6	May 2	76	153	2.01	Sept. 15, 1930	May 7, 1930	5	218	87	27	Do.
12	Feb. 10	do	do	Feb. 13	4	May 6	82	161	1.96	Jan. 3, 1932	May 14, 1930	8	692	94	27	Do.
13	Feb. 11	Feb. 10	do	Apr. 7	56	Sept. 18	164	323	1.97	Aug. 23, 1930[3]	Sept. 24, 1930	6	------	226	([4])	Do.
14	do	do	do	Mar. 28	46	July 27	121	281	2.32	June 26, 1930	Aug. 9, 1930	13	135	180	([4])	Do.
15	Feb. 13	Feb. 12	Feb. 20	Mar. 16	32	Sept. 26	194	608	3.13	July 21, 1932	Oct. 2, 1930	6	889	232	([4])	Whole-wheat flour.
16	Feb. 15	Feb. 13	do	Mar. 25	40	Aug. 28	156	528	3.38	Oct. 26, 1931	Sept. 3, 1930	6	618	202	([4])	Do.
17	Feb. 12	Feb. 12	do	Mar. 21	37	July 30	131	408	3.11	May 8, 1932	Aug. 1, 1930	2	816	170	([4])	Do.
18	do	Feb. 11	Feb. 13	Apr. 16	64	June 12	57	21	.37	Feb. 20, 1931	June 16, 1930[3]	------	373	------	([4])	White flour.
19	do	Feb. 12	Feb. 20	May 12	89	Aug. 9	89	17	.19	Mar. 16, 1931	Jan. 12, 1931	156	397	334	([4])	Do.
20	do	do	do	Apr. 16	63	Feb. 18[5]	308	163	.53	([3]) 1930	July 15, 1931	147	------	518	([4])	Oatmeal.
21	do	do	do	Apr. 3	50	Dec. 19	260	131	.50	Dec. 16, 1931	Mar. 16, 1931	87	672	397	([4])	Do.
22	do	do	do	Mar. 24	40	Sept. 8	168	74	.44	Dec. 27, 1931	Oct. 25, 1930[3]	------	683	------	([4])	Do.
23	Feb. 14	Feb. 14	do	Mar. 28	42	Jan. 8[5]	286	956	3.34	Mar. 3, 1931	Jan. 23, 1931	15	382	343	([4])	Corn meal.
24	Feb. 16	Feb. 16	do	Apr. 4	47	Sept. 22	171	412	2.41	Oct. 15, 1931	Jan. 10, 1931	110	606	328	([4])	Do.
25	do	do	do	Mar. 18	30	Aug. 21	156	134	.86	Mar. 9, 1930[3]	Sept. 19, 1930	29	------	215	([4])	Do.

[1] Only the viable eggs have been counted. Many infertile eggs are laid after the last viable egg, but these are not considered in this table.
[2] Taken in copulation.
[3] Escaped.
[4] Room temperature.
[5] 1931.

TABLE 11.—*Data concerning oviposition and longevity of Tribolium confusum*

Pair no.	Date male emerged	Date female emerged	Date mated	Date first viable egg laid	Length of preoviposition period	Date last viable egg laid	Length of oviposition period	Total viable eggs laid	Average viable eggs laid per day	Date male died	Date female died	Length of postoviposition period [1]	Longevity of male	Longevity of female	Temperature	Food
					Days		*Days*	*No.*	*No.*			*Days*	*Days*	*Days*	°*C.*	
1	Dec. 3, 1929	Dec. 8, 1929	Dec. 9, 1929	Dec. 20, 1929	12	Oct. 10, 1930	294	169	0.57	July 8, 1931	Nov. 10, 1930	31	582	337	27	White flour.
2	Dec. 14, 1929	Dec. —, 1929	Dec. 16, 1929	Dec. 21, 1929	-----	Dec. 2, 1930	346	161	.47	Aug. 4, 1931	Apr. 20, 1931	139	598	-----	27	Do.
3	(2)	(2)	do	do	-----	Nov. 20, 1930	334	230	.69	Nov. 8, 1930	Feb. 16, 1931	88	-----	-----	27	Do.
4	(2)	(2)	do	Dec. 23, 1929	-----	June 26, 1930	185	158	.85	Aug. 4, 1931	July 7, 1930	11	-----	-----	27	Oatmeal.
5	Dec. 18, 1929	Dec. 18, 1929	Dec. 19, 1929	do	5	Mar. 21, 1930	88	125	1.42	Jan. 8, 1930	July 16, 1931	482	21	575	27	Do.
6	Dec. 28, 1929	Jan. 2, 1930	Jan. 4, 1930	Jan. 23, 1930	21	May 1, 1930	98	270	2.76	Feb. 10, 1931	May 7, 1930	6	409	125	27	Middlings.
7	(2)	(2)	Dec. 16, 1929	Dec. 21, 1929	-----	Aug. 2, 1930	224	209	.93	Sept. 18, 1930	Sept. 16, 1930	45	-----	-----	27	Bran.
8	Dec. 16, 1929	Dec. 26, 1929	Dec. 27, 1929	Jan. 6, 1930	11	Aug. 10, 1930	216	331	1.53	Mar. 17, 1931	Aug. 19, 1930	9	456	236	27	Do.
9	Jan. 27, 1930	Jan. 27, 1930	Jan. 29, 1930	Feb. 3, 1930	7	Oct. 8, 1930	247	412	1.66	Jan. 9, 1931	Jan. 20, 1931	104	347	358	27	Do.
10	do	do	do	do	7	Nov. 12, 1930	282	424	1.50	Jan. 8, 1931	Jan. 5, 1931	54	346	343	27	Do.
11	do	do	do	Feb. 1, 1930	5	Dec. 27, 1930	329	342	1.04	May 2, 1931	Jan. 6, 1931	10	460	344	27	Do.
12	do	do	do	do	5	Nov. 17, 1930	289	282	.97	Apr. 28, 1931	Jan. 9, 1931	53	456	347	27	Do.
13	do	do	do	Jan. 31, 1930	4	July 31, 1930	181	328	1.81	Aug. 3, 1932	Dec. 16, 1931	503	919	688	27	Whole-wheat flour.
14	do	do	do	Feb. 2, 1930	6	Nov. 18, 1930	289	905	3.13	Apr. 5, 1932	Dec. 1, 1930	13	799	308	27	Do.
15	do	do	do	Feb. 6, 1930	10	Oct. 9, 1930	245	330	1.35	May 2, 1932	Oct. 3, 1931	359	826	614	27	Do.
16	Feb. 8, 1930	Feb. 7, 1930	Feb. 13, 1930	Feb. 17, 1930	10	July 28, 1930	161	389	2.42	Feb. 25, 1930 [3]	Jan. 2, 1932	523	-----	394	27	Do.
17	Feb. 7, 1930	Feb. 8, 1930	do	Feb. 18, 1930	10	Oct. 26, 1930	250	677	2.71	Jan. 30, 1932	Oct. 30, 1930	4	722	264	27	Do.
18	Feb. 12, 1930	Feb. 10, 1930	do	do	8	Aug. 17, 1930	180	491	2.73	Nov. 14, 1931	Aug. 20, 1930	3	640	191	27	Do.
19	Jan. 27, 1930	Feb. 4, 1930	Feb. 6, 1930	Apr. 25, 1930	80	do	114	521	4.57	July 29, 1930 [3]	Aug. 26, 1930	9	-----	203	(4)	Do.
20	do	Jan. 30, 1930	Feb. 3, 1930	Apr. 27, 1930	87	Sept. 19, 1930	145	596	4.11	Oct. 27, 1930 [3]	Sept. 25, 1930	6	-----	238	(4)	Do.
21	do	Jan. 27, 1930	Jan. 29, 1930	Feb. 4, 1930	8	Apr. 12, 1931	432	882	2.04	Dec. 19, 1932	Feb. 22, 1932	316	1,057	756	(4)	Do.
22	Jan. 29, 1930	Jan. 29, 1930	do	Apr. 6, 1930	67	Feb. 17, 1931	317	563	1.78	Oct. 4, 1930	Aug. 28, 1932	558	248	942	(4)	Do.
23	Jan. 27, 1930	Jan. 30, 1930	Feb. 3, 1930	Mar. 19, 1930	48	May 12, 1931	419	945	2.25	July 14, 1932	Sept. 3, 1932	480	899	947	(4)	Do.
24	do	Jan. 31, 1930	do	Mar. 22, 1930	50	Dec. 5, 1930	258	729	2.83	June 28, 1932	July 20, 1931	227	883	535	(4)	Do.
25	Jan. 30, 1930	Feb. 4, 1930	Feb. 6, 1930	Mar. 17, 1930	41	Nov. 24, 1930	252	976	3.87	Nov. 5, 1933	Jan. 8, 1931	45	1,375	338	(4)	Do.

[1] Only the viable eggs have been counted. Many infertile eggs are laid after the last viable egg, but they are not considered in this table.
[2] Taken in copulation.
[3] Escaped.
[4] Room temperature.

INTERRELATION WITH OTHER ANIMALS

MEDICAL IMPORTANCE

Flour beetles have never been considered of medical importance, although it is known that many live larvae, and other stages as well, are accidentally swallowed in the eating of uncooked breakfast foods, dried fruits, nuts, or chocolate.

In an article treating of infestation of human beings by the cestode *Hymenolepis diminuta* Rud., in Japan, Momma (*69*) lists *Tribolium ferrugineum* in a series of insects which have been determined by Hongo to be intermediate hosts of this tapeworm in that country. He also states his belief that infestation of humans is due to the accidental swallowing of an infested individual of any of that series of intermediate hosts.

ENEMIES OF TRIBOLIUM BEETLES

PROTOZOAN DISEASES

One disease, caused by a coccidian of the genus *Adelina* (Park (*75*)), is of rather common occurrence among species of *Tribolium*. This disease was first reported by Riley (*85*) in 1921 in Minnesota and mentioned in 1922 by Riley and Krogh (*86*), both of these references being merely records of the observance of the disease.

The parasite invades the fat cell of the host. The larvae, pupae, and adults are affected, and within a few months the disease may practically exterminate an entire culture of beetles. During the present investigations the author often noticed that numbers of larvae and beetles would die from some disease. Specimens were given for examination to G. F. White, who reported them to have died from this protozoan infection. To date the disease has been reported only in *Tribolium confusum* and *T. castaneum*.

Another protozoan disease of these flour beetles was described briefly by White in 1923 (*103*). The causal protozoan is a neosporidian which invades the fat body of the larva, and may also be found in the pupa and adult beetle. Late in the course of the disease the sick larvae may be less active, slightly distended, and more opaque. After a few months most of the diseased insects have died.

It is not known whether these diseases can be used in the artificial control of these flour beetles.

MITES AFFECTING TRIBOLIUM

The most common parasite of the flour beetles is the mite *Acarophenax tribolii* Newstead and Duvall (fig. 20). This tarsonemid was described from *Tribolium confusum* and *T. castaneum* in wheat from Australia (*72*), but the beetles may have become infested in England. Newstead and Duvall also reported the mite from *Tribolium* in "Plate maize." These mites were first noticed in North America by the author in 1930 and were identified by H. E. Ewing. Specimens were recorded from the District of Columbia, Virginia, Mississippi, and Texas, and specimens, tentatively identified by the author as the above species of mite, were found on *Tribolium* adults in Kansas and Oklahoma. Holdaway (*52*) also reported this mite from *T. confusum* in Minnesota. The author has found these mites also on *Gnathocerus cornutus* Fab., *Palorus ratzeburgii* Wissm., and *Latheticus oryzae* Waterh. A description and full account of their life history is given by Newstead and Duvall (*72*). These mites cling to the body of their host and draw their nourishment from it, and it seems that they do little more than irritate the adult beetles. Adults seem to be more heavily infested, but all stages may be attacked. Many eggs are destroyed by the gravid female mites that attack the beetle's eggs a few days before the young mites are ready to come forth. Then the mother dies, and the young mites emerge, leaving her body an empty shell.

FIGURE 20.—A flour beetle (*Tribolium castaneum*) with several mites (*Acarophenax tribolii*) attached to the ventral surface, × 20.

Another mite, the common *Pediculoides ventricosus* Newport, sometimes infests the immature stages of *Tribolium*, killing all individuals that it attacks. *Pediculoides* was observed in the laboratory in rearings of *Tribolium castaneum* and *T. confusum* in 1930, but it appeared that these beetles were not preferred hosts and were not bothered when sufficient lepidopterous larvae were present.

HYMENOPTEROUS PARASITES

Two hymenopterous parasites, both in the family Bethylidae, have been bred from *Tribolium*. Only one of these, *Rhabdepyris zeae* Turner and Waterston (fig. 21), has been recorded in nature as a parasite of the flour beetles. Gahan (*44*) gives records of *Rhabdepyris* as a parasite of *Tribolium* in Indiana, Louisiana, and possibly from *Tribolium* in a shipment of grain from West Africa to England. Specimens in the United States National Museum from Texas and Florida also belong to this species.

The other bethylid, *Sclerodermus immigrans* Bridwell, was experimentally bred from *Tribolium* in Hawaii by Bridwell (*11*) in 1920 but has not been recorded as attacking it in nature.

PREDATORS

COLEOPTERA

The cadelle, *Tenebroides mauritanicus* L., has been reported as attacking flour beetles by Johnson (*57, no. 4*), Washburn (*99*), and Durrant and Beveridge (*40*). These observations concern mainly the adult cadelle attacking flour beetle larvae. The experiments of Back and Cotton (*6*) show that cadelle larvae are not normally predacious and will attack other insects very infrequently and then usually do not feed on the carcass of their victim. In recent experiments in the laboratory, cadelle larvae showed no tendency to attack larvae, pupae, or adults of *Tribolium*.

"A species of *Rhizophagus*" has been reported as preying on *Tribolium castaneum* by Muller (*41*) in peanuts arriving in London from Sierra Leone.

HEMIPTERA

Several species of predacious Hemiptera frequent flour mills, but none has been definitely associated with *Tribolium* except by Roubaud (*87*). In April 1933 numbers of a small anthocorid were observed by the author in a breeding jar containing no other possible host but *T. confusum* feeding in cracked grain and flour that had

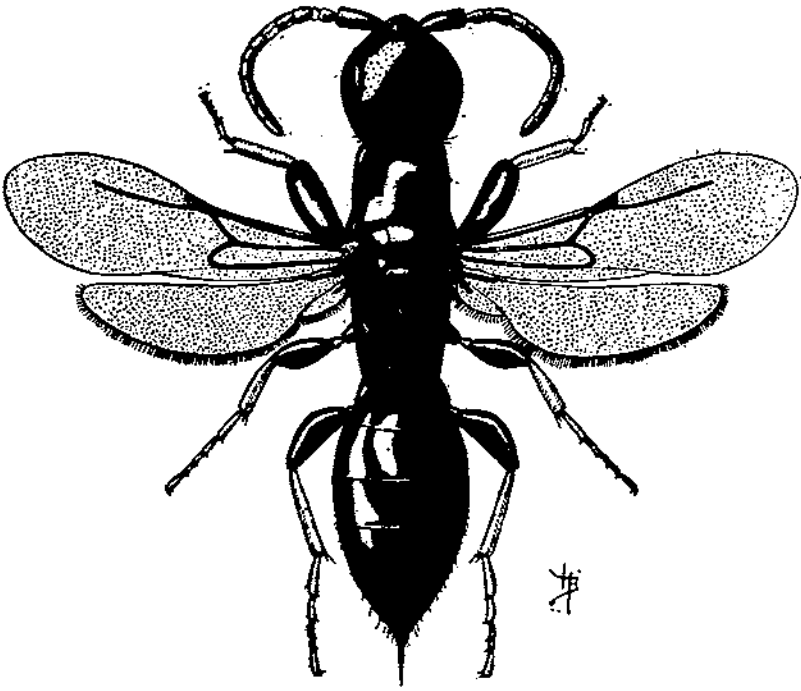

FIGURE 21.—*Rhabdepyris zeae*, a hymenopterous parasite of the flour beetles: Adult female, × 27.

been collected in a flour mill in Washington, D. C., in December 1932 and had not been molested since that date. Specimens were identified by H. G. Barber as *Xylocoris cursitans* Fallen, which is generally predacious on small, soft-bodied insects and in this case was undoubtedly attacking the small larvae.

MISCELLANEOUS ENEMIES

Mice (*Mus musculus*) may also be considered as enemies of *Tribolium*, as they sometimes eat these beetles, as well as many other kinds of insects.

TRIBOLIUM AS A PREDATOR

There are several records, more or less definite, of *Tribolium* beetles preying on larvae of the Mediterranean flour moth and other insects.

A note by Johnson (*56*) is interesting, although more humorous than practical. He says:

> A miller in California called my attention to the fact that he had seen this beetle feeding on the larvæ of the Mediterranean flour moth (*Ephestia kühniella*) and even contemplated the erection of a plant where he could breed the beetle, so he could turn them loose on the terrible flour moth, which everywhere filled his mill.

Washburn (*99, pp. 36–37, 44*) states:

> *Tribolium confusum* * * * has been known to devour the pupæ of the flour moth. The so-called "bolting-cloth beetle" (*Tenebroides mauritanicus*) of California eats larva and pupa of the flour moth and larva and adult of Tribolium. * * * It [*T. confusum*] is said to attack and eat the larvæ of the Mediterranean Flour Moth.

Alden and Farlinger (*1, p. 482*) state:

> The rust red flour beetle [*Tribolium ferrugineum* Fab.] also fed on Sitotroga [*cerealella*] eggs and the dead bodies of the adults.

The author has never observed *Tribolium* actually attacking any other living insects and does not believe that it does so normally, except perhaps in the case of eggs and very young larvae. However, it has been frequently observed that in cases where *Tribolium* and other species of insects are present in the same breeding jar the *Tribolium* will soon crowd out the other insects. Whether this is due to the killing of the other insects or to mechanical crowding is a matter of conjecture. It is probably due mainly to the breaking of the eggs and the killing of the young larvae by the adult flour beetles as they run around over the flour and, to a lesser extent, to the actual devouring of eggs and young larvae by these flour beetles. This same reduction in the number of eggs is found in unmixed lots of *Tribolium* and is undoubtedly caused by the mechanical breaking of the eggs by the movements of the adults.

Kotinsky (*60*) records *Tribolium castaneum* as an enemy of the harmful leaf-cutting bee *Megachile palmarum* Perkins in Honolulu. He was not certain whether the *Tribolium* actually preyed on the bee larva or merely fed on the pollen in the cells, but in either case the bee larva died.

In India, *T. castaneum* has been noted associated with the lac insects (*Tachardia*) by Mahdihassan (*68, p. 69*) and by Imms and Chatterjee (*54*) who state:

> We have also dissected this insect from among the chambers of the lac where its larval stage is spent. * * * It is probable that it feeds only on the lac and not on the Tachardiae, but it is to be regarded as one of the more important Coleopterous enemies of lac.

CONTROL MEASURES

CONTROL IN FLOUR MILLS

Flour mills are open to infestation from three main sources, (1) the grain stream, (2) returned infested flour, and (3) used bags and second-hand machinery. As has already been stated, *Tribolium* beetles cannot live in perfectly sound grain, but nearly all lots of grain are damaged to a certain extent, either through rough handling or because of the work of the true grain weevils, and so any *Tribolium* present can live until they reach and infest the flour mill.

After a flour mill is once infested with these beetles, two satisfactory methods of control are by fumigation or superheating. Other methods, such as cleaning out the machinery regularly, local fumigating, and spraying can be used in conjunction with the above methods. So far biological control has not proved practical.

Perhaps the most satisfactory, and certainly the most widely used, fumigant for flour beetles is hydrocyanic acid gas (*4, 7, 32*). Although this gas is deadly to human life it can be handled with comparative safety by well-trained fumigators. Chloropicrin (*34, 96*) is also used as a mill fumigant, and when properly applied is quite effective. Owing to its lachrymatory effect it has not become so popular a mill fumigant as hydrocyanic acid gas.

FIGURE 22.—Bases of elevator legs after application of the heat method of control. Large numbers of beetles have crawled out of the cracks and died on the floor. (Back.)

Control by heat (*4, 18, 32, 33, 34, 48*) is practiced to a certain extent (fig. 22), and this method has the advantage of being harmless to the operator.

Prepared flours and cereals put up in package form are frequently infested by flour beetles. Such products should be sterilized by heat derived from steam, hot air, or electricity, and should pass directly from the sterilizer to the packer where the cartons are packed and sealed. This process, if properly carried out will insure a product free from insects. Electrical machines are now on the market for sterilizing small packages of prepared cereals by disruptive discharge (*45*). This method shows considerable promise.

CONTROL OF FLOUR BEETLES IN HOUSES

The method used for the control of these insects in flour and cereals in dwellings are necessarily quite different from those advocated for use in mills and warehouses.

These pests, in practically all cases, are originally brought into the house through infested flour or breakfast cereals, and when such material is allowed to stand for some time the infestation may spread to nearly every article of food in the house. Whenever there is any reason to suspect the presence of beetles, larvae, or eggs, the safest and simplest procedure is to place the product in a shallow pan and heat it in an oven for a time with a very low fire. This treatment will kill all stages of the insects without injuring the flour or cereal, and is especially useful in the frequent cases where, although no beetles or larvae are to be found, eggs may have been deposited in the food, which later would develop into larvae and beetles. The exposures shown in table 12 will kill all stages of these insects.

Table 12.—*Temperatures and time of exposure necessary to kill all stages of the flour beetles in flour, meal, or cereals*

Temperature (°C.)	Exposed individuals	In 1 inch of flour	In 3 inches of flour
50	1½ hours	4 hours	8 hours.
60	15 minutes	45 minutes	4 hours.
70	10 minutes	40 minutes	2½ hours.
80	8 minutes	30 minutes	2 hours.

Temperatures below 79° C. are not likely to injure flour or cereal, but 80° and above may scorch flour, and so should be avoided. Breakfast cereals may, however, be heated to about 90° without being injured. Further data on oven heating to kill flour beetles is given by Chapman (*17*).

When these beetles have already become established in a pantry or flour bin the best procedure is to destroy all foodstuffs known to be infested, sterilize by the foregoing method all those that may be infested, and give the entire kitchen and pantry a thorough cleaning, including scalding of all cracks with boiling water.

In cases where it is impossible to rid a place of insects without fumigation, the directions given in the articles referred to should be studied and carefully followed.

SUMMARY

The confused flour beetle, *Tribolium confusum* J. du V., and the rust-red flour beetle, *T. castaneum* (Hbst.), are by far the most abundant and destructive beetles infesting flours and other prepared cereal products. These insects are cosmopolitan and are now recorded as pests in practically every civilized country of the world.

A partial revision of the genus *Tribolium* is given, in which the name *castaneum* Herbst is shown to be the correct name for the species commonly known as *ferrugineum* Fab. Seven species are included in the genus. These are *castaneum*, *confusum*, *madens*, *destructor*, *gebieni*, *indicum*, and *myrmecophilum*.

These beetles, excepting *myrmecophilum* and *gebieni*, are probably native to the region comprising southwestern Asia and the eastern Mediterranean lands. Their original habitat was under the bark of trees and in rotting logs, where they probably lived as scavengers.

Both *T. confusum* and *T. castaneum* are cosmopolitan, but *T. confusum* is more common in temperate regions, and *T. castaneum* is more of a subtropical insect. *T. madens* has been recorded from North America, Europe, and Egypt, and *T. destructor* from Germany and the Netherlands. *T. indicum*, *T. gebieni*, and *T. myrmecophilum* apparently have a very limited range, the first being recorded from India and northern Africa, the second only from Paraguay, while the last is known only from southeastern Australia. Most of the many references to these beetles in literature are records of the damage done by them.

The flour beetles are particularly injurious in flour mills and in other establishments that prepare cereal products. They are nearly omnivorous and have been reported breeding in and damaging flour and all other prepared cereal products, grain and seed, animal matter and especially dry insects specimens, yeast, nuts, dried fruits, chocolate, certain spices, and other miscellaneous plant products.

The eggs, which are laid directly in the flour or other food material, are covered with a sticky substance that causes the foodstuffs to adhere to them and often completely cover them.

The incubation period for *T. castaneum* averaged 4 days at 30° C., 5.2 days at 27°, 6 days at 25°, and about 8.8 days at room conditions where the temperature averaged 22°. The incubation period for *T. confusum* averaged 6.8 days at 27°, and 12.8 days at room conditions where the temperature averaged 21°.

The number of larval instars ranges from 5 to 11 or more, the usual number being 7 or 8. Environmental conditions, especially food and temperature, influence the number of instars considerably. However, there may be considerable individual variation in the number of instars of larvae reared under identical conditions.

The duration of the larval period ranges from 22 to over 100 days according to the influence of environment and the effect of individual variation. The optimum temperature for development seems to be close to 30° C. for both species. Of the foods used, whole-wheat flour was most favorable for development, followed by middlings, bran, corn meal, and white flour in the order named. Measurements for the various stages and for the larval instars, including the width of the head capsule, are given.

The average pupal periods were, for *T. castaneum* at 30° C., 5 days, at 27°, 7.1 days, at 25°, 8.8 days, at room temperature in early summer, 8.5 days; and for *T. confusum* at 27°, 7.9 days in continuous light and 8.7 days in continuous darkness. Adult males and females are so nearly alike in external appearance that they are difficult to separate, although the sexes can be readily recognized in the pupal stage by the characteristic shape of the venter of the last abdominal segment.

Adults of *T. castaneum* can fly short distances, but adults of *T. confusum*, although provided with wings, have never been observed to fly. Adults of both species possess scent glands that give off a pungent odor.

Breeding continues the year round in heated buildings, but in unheated mills in the Northern and Central States only adults are present during the winter.

Adults have been known to live as long as 3 years and 271 days. The average longevity of the adults used in the oviposition experiments was as follows: *T. confusum* males, 634 days, females, 447 days; *T. castaneum* males, 547 days, females, 226 days. *T. confusum* males have proved fertile at 3 years, 76 days of age. The greatest age at which a female laid fertile eggs was 1 year and 94 days.

Resistance to starvation varies inversely with the temperature, and the two species seem equally resistant. The longest survival periods for adults without food are as follows: At 30° C., 18 days, at room temperature, 23 days, at 15°, 27 days, at 10°, 51 days. The longest survival periods for larvae without food were 23 days at 30°, 46 days at ordinary room conditions, and 54 days at 15°.

The longest oviposition periods recorded were 432 days for *T. confusum* and 308 days for *T. castaneum*. The average oviposition period for *T. confusum* was about 8 months, while that of *T. castaneum* was about 5½ months. The average number of eggs laid per day during the entire oviposition period of any female was 2 or 3, and the highest number recorded in 1 day was 13. The greatest number of viable eggs laid by a single female during its entire oviposition period was 976 for *T. confusum* and 956 for *T. castaneum*. The average number laid by *T. confusum* females was 458 while that of *T. castaneum* was 327.

T. castaneum has been experimentally proved to be one of the intermediate hosts of the tapeworm *Hymenolepis diminuta* in Japan.

A disease caused by a coccidian, *Adelina* sp., is often found in the rearings of *Tribolium* and kills large numbers of the insects. The mite *Acarophenax tribolii* is the most common parasite of these beetles. Another mite, the common *Pediculoides ventricosus*, sometimes attacks *Tribolium*. The hymenopterous parasites *Rhabdepyris zeae* and *Sclerodermus immigrans* have been recorded from *Tribolium* but seem to be rather rare. Predators attacking *Tribolium* are the hemipteron *Xylocoris cursitans* and adults of the cadelle, *Tenebroides mauritanicus*. Adults of *Tribolium* may themselves be predatory to a certain extent.

Control methods include fumigation with hydrocyanic acid gas or chloropicrin, and the use of heat.

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