Illustrated identification keys for *Trogoderma granarium*, *T. glabrum*, *T. inclusum* and *T. variabile* (Coleoptera: Dermestidae) and other *Trogoderma* associated with stored products

H. J. Banks

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Cover photo: larva of Trogoderma variabile (photo: John Green)
Illustrated identification keys for *Trogoderma granarium*, *T. glabrum*, *T. inclusum* and *T. variabile* (Coleoptera: Dermentidae) and other *Trogoderma* associated with stored products.

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Abstract

The stored product pests, *Trogoderma granarium*, *T. glabrum*, *T. inclusum* and *T. variabile*, are objects of quarantine in Australia. Conclusive identification of these pests is important as their detection may require major expenditure and inconvenience from measures designed to contain or eradicate them. A key to distinguish adults, pupae and larvae of these important pest species from allied species is presented, together with optical and electron micrographs of important features to assist the use of the key. Details of the male and female genitalia and pupal gin traps of the important pest *Trogoderma* and related species are figured. These provide conclusive diagnostic features. Some details of closely related Australian *Trogoderma*-like species are given. These are potentially confusible with the major pest *Trogoderma*, but are distinguished particularly, as larvae, by presence of two setae of equal length on the pretarsal claw, as pupae by the absence of gin traps and, as adults, by the presence of only a single band of pale colouration and hairs on the elytra. The major pest species have two setae of unequal length and three bands of hairs and pale coloration on the elytra respectively. Practical details are given for the preparation of suitable mounts for identification, including how to carry out the specialized and skilled dissection required.

An edited translation of Varshalovich's (1975) key to adults of *Trogoderma* associated with stored products is given.

1. INTRODUCTION

The genus *Trogoderma* Berthold contains some of the world's most feared stored product pests. Because of the damage they can cause, several species are objects of quarantine in many countries. *Trogoderma granarium* Everts, *T. glabrum* (Herbst) and *T. inclusum* Le Conte have been gazetted in Australia as Quarantinable Diseases under the Quarantine Act 1908-1973 (Quarantine Proclamation 68P, 27 February 1973). *T. variabile* is under quarantine restriction in New South Wales (Govt. Gazette, 11, 22 Jan 1982 under Plant Diseases Act 1924, Sect. 5A). It is important to be able to distinguish those species which are subject to quarantine from the closely related ones which may also be associated with stored products. Decisions requiring use of extensive resources, and giving rise to considerable inconvenience and cost, may have to be made on the basis of identification of a small number of specimens, or even from a single larva or exuvia. The available keys are inadequate as they do not take into account the extensive, but little known Australian *Trogoderma*-like fauna, most are based only on regional fauna and the nature of the illustrations do not allow a non-specialist entomologist to be confident of identifications. Additionally, there is no easily accessible collection of illustrations of male and female genitalia of *Trogoderma* spp., although these give the most easily used diagnostic characters.

This key and comments uses the synonymy and generic classifications of Mroczkowski (1968) and Zhantiev (1976). The synonymy used here is summarized in Table 1.
Table 1. Synonomy for *Trogoderma* species used in this key.

<table>
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| *T. granarium* Everts| *T. afrum* Priestner  
*T. khapsra* Arrow      |
| *T. glabrum* (Herbst)| *T. nigrum* (Herbst)  
*T. boron* Beal         |
| *T. inclusum* Le Conte| *T. versicolor* as used by Beal (1954, 1956), Park (1941), Hinton (1945), Hadaway (1956), Howe and Burges (1956) |
| *T. teukton* Beal    | *T. glabrum* as used incorrectly in Beal (1954)  
*T. oothecophilum* Chao & Lee  |
| *T. variabile* Ballion| *T. persica* Pic  
*T. persicum* as used by Chao & Lee (1966)  
*T. parabile* Beal |


The keys were checked against named material from the cultures of the Pest Infestation Control Laboratory, Slough, U.K. (now known as MAFF, Central Science Laboratory); the Citrus Experiment Station, Riverside, U.S.A.; the Yokohama Plant Protection Station, Yokohama, Japan and the collection of the British Museum (National History), London, U.K. Material was also obtained from Dr Mroczkowski, Polish Academy of Sciences, Warsaw and Dr Chao, Institute of Zoology, Shanghai. The draft keys were tested by groups of professional entomologists unfamiliar with the identification of *Trogoderma* during several training courses, and revised in the light of this experience.

The keys are designed to give conclusive identifications of larvae, pupae or adults of the four common, widespread and economically important species of *Trogoderma* - *T. granarium*, *T. glabrum*, *T. inclusum* and *T. variabile*; hereafter referred to as the 'critical' species. Illustrated keys to these four species and distinguishing features from other dermestids found in UK have been published (Peacock 1993) but these do not distinguish the critical species from other *Trogoderma*. An edited translation of a key by Varshalovich (1975) which covers the adults of almost all non-Australasian *Trogoderma* species is given in Appendix 1.
Only one of the critical species considered here, T. variabile, is known to be established in Australia. This species is present throughout the wheatbelt of mainland Australia (E.J. Wright, pers. comm.). The absence of the important Trogoderma pests from Australia is an important advantage in the marketing of major export commodities such as grains. However, Australia has 43 described endemic Trogoderma species (Armstrong 1942, 1949; Mroczkowski 1968), some of which are found associated with stored products and could be intercepted by overseas authorities. Misidentification of an endemic species from an exported commodity as one of the major Trogoderma pests might have adverse repercussions on the marketing of Australian export products. One endemic species, T. carteri Armstrong, has already been intercepted overseas in an export commodity (Ward 1965). The keys take the known Australian Trogoderma into account and provide some features whereby they can be distinguished from the critical species. The endemic Trogoderma exhibit a number of features, not found in the Nearctic or Palearctic Trogoderma, which are sufficiently distinctive to merit the removal of the endemic species from the genus Trogoderma in the sense of Beal (1954). The keys also distinguish the critical Trogoderma spp. from Reesa vesupulae Milliron, a closely related species that is currently extending its world range rapidly and is established in Australia.

An important prerequisite for identification of Trogoderma to species level is proper preparation of the specimens. This is a skilled operation, requiring practice and preferably demonstration to the novice by persons who carry it out routinely to a high level of success. Details of the method of preparation of larvae and of adult genitalia are given in detail to assist this difficult task.

2. PREPARATION OF MATERIAL

2.1 Apparatus required

Binocular dissecting microscope (10x - 50x magnification)
Compound microscope (10x - 400x magnification)
Scissors for eye surgery - microscissors (ordinary dissecting scissors are too large)
Routine equipment for slide preparation
Bunsen, waterbath and test-tubes (5 x 1/2")
Dissecting needles (preferably tungsten points) (see Appendix 2 for making tungsten points)
Single-edge razor blades
'Stroyan's mountant' (see Appendix 2 for recipe)
Chloral-phenol (50% w/w) (see Appendix 2 for recipe) [CAUTION - very caustic to skin, dangerous to eyes]
Potassium hydroxide solution (5%, aqueous) [CAUTION - caustic to skin, dangerous to eyes]
Decon 90 surfactant (a concentrated surface-active agent).

2.2 Procedure for preparation of larvae

The objective is to dissect and clean the specimen and then mount the head and mandibles under one coverslip and the body under another coverslip on the same slide, so that all of the important features are easily seen, and different parts of the same specimen do not become separated.
Place the fresh or alcohol-preserved larva with its ventral surface upwards on a microscope slide. Do not allow preserved specimens to dry out before dissection, as this introduces bubbles and it can become brittle. With a razor blade, slice the head transversely just posterior to the mandibles so that the mandibles, palpi and antennae are all on the excised portion (Figure 1). With microscissors, cut the larva longitudinally along the ventral lower surface, passing between each pair of legs. The cut should be continued to the last abdominal segment to ensure that, on mounting, the specimen can be opened out completely. To begin the cut, the point of one blade of the scissors should be inserted into the opening formed by removal of the anterior part of the head. Place both parts of the larva in 5% KOH (about 2 mL) in a test tube. Heat in a boiling water bath for 5 mins. Remove and rinse once in water. Place in chloral-phenol (about 1 mL) and heat in a boiling water bath for at least a further 5 mins (the specimen can be heated for up to 30 mins without damage). [CAUTION - Heating in chloral-phenol should be carried out in a well ventilated area with precautions to ensure that the hot liquid does not come into contact with skin - highly caustic - or eyes - dangerous, burns. If the waterbath boils dry, caustic fumes may be given off.] Drain the excess chloral-phenol from the head section. Remove the mandibles and any remains of the palpi that may otherwise obscure the epipharynx with dissecting needles. Mount the head section in Stroyan’s medium under a coverslip so that the front of the head is directly on the slide and with the labrum hinged outwards so that the inside surface and epipharynx are clearly visible from above. Drain excess clearing fluid from the posterior part of the larva. If there are many setae on the final two segments, denude one side so the surface of the segments, including the antecostal suture, can be seen. Mount in Stroyan’s medium under a second coverslip with the dorsal side uppermost and the two halves of the ventral side spread out to give a flat specimen. If the ventral side is left under the dorsal side, it is sometimes difficult to see fine details of some setation.

Fig. 1. Dissection of larval head to reveal the epipharynx. The dotted line shows the plane of cutting.
2.3 Procedure for preparation of larval and pupal exuviae

Place the exuviae in undiluted Decon 90, a concentrated surfactant, for at least 10 mins (Banks and Williams 1972) to soften. Take care to disturb the exuviae as little as possible during this process, as very old, brittle skins may break before becoming soft. Rinse twice in water. Bubbles, which are often troublesome, particularly in the legs or antennae, can be removed by applying a gentle vacuum to the preparation while in water, using a water pump and vacuum dessicator. When the vacuum is relieved water usually enters the hollow areas formerly filled with air. For larval exuviae, continue the existing emergence crack along the dorsal midline to the end of the abdomen by cutting with microscissors. For pupal exuviae, remove the pupal exuvia from the posterior end of the larval skin using a pointed probe. The larval skin enclosing the pupal exuvia does not require dissection, as it is fully split down the midline by the emergence of the adult. Mount in Stroyan’s medium. For larval exuviae, mount with ventral surface uppermost and with the two halves of the dorsal surface folded out to give a flat preparation. The mandibles may be removed using dissecting needles to allow inspection of the epipharynx. However, with practice, it is possible to move the mandibles by pressing on the coverslip so that the mouthparts open and the epipharynx can be seen without dissection. Pupal exuviae should be mounted in Stroyan’s medium with the dorsal surface uppermost and the skin stretched out to allow the gin traps to be seen easily.

2.4 Procedure for preparation of adults

Contrary to normal coleopterist’s practice, which is to mount insects in a dry form, it has been found most convenient to dissect the adult insect completely and to mount the separated parts on a slide. This procedure facilitates inspection of features such as antennae, wings, tarsi and elytral pattern and provides a permanent preparation. It does, however, make the colour pattern of the elytral setae more difficult to see, although this is possible using indirect lighting. It is also not possible to make electron micrographs of the specimen. Thus, it may sometimes be appropriate to mount the adult specimen on points in the normal fashion and only treat the abdomen as given below.

Dry specimens should be soaked in undiluted Decon 90, for at least an hour, preferably overnight, but recently killed or alcohol-preserved specimens require no treatment. Heat the specimen in 5% KOH (about 2mL) in a boiling water bath for 5-10 mins. Rinse with water. Remove the abdomen and split it down one side completely, taking care not to damage the genitalia, located in the terminal segments. Treat again with 5% KOH as before. Rinse with water. Dissect out the genitalia, complete with all associated structures. The genitalia may already be everted and easy to remove. Otherwise they can be found in the last two or three visible abdominal segments. It is unnecessary to remove the ring segments associated with the genitalia when preparing the mount. Removing the ring segment is often difficult and the genitalia may be damaged in the process. Diagnostic characters are usually easily seen in undissected material (e.g. Figure 56) and the difficult additional manipulation can sometimes result in damage to important features. Clear the genitalia by heating for 5 minutes with chloral-phenol in a boiling water bath. Mount in Stroyan’s medium on a cavity slide beside the cavity on the flat portion. Heat the remaining parts of the specimen in chloral-phenol in a boiling water bath for 5 -10 mins. Dissect into parts, separating the head with antennae from the thorax and the elytra. The thorax should be split laterally so that the upper and lower halves are separated. Drain off excess mountant and mount with the abdomen in the cavity of the slide in Stroyan’s mountant.

Alternative procedures for preparation of female genitalia, specifically, of Trogoderma spp. (Lovitt et al. 1968) and for male and female genitalia (Peacock 1993) have been published.
3. KEYS TO T. GRANARIUM, T. GLABRUM, T. INCLUSUM AND T. VARIABILE

The descriptions and keys given below are necessarily complex and include some apparently redundant information in order to attempt to exclude species yet to be discovered or recognised. Section 3.1 provides an alternative and rapid, preliminary diagnosis scheme designed to recognise whether a specimen is likely to be one of the critical species without using a full formal key. Where there are indications that a specimen is probably a pest *Trogoderma*, the full key, Section 3.2, can then be used to provide a firmer diagnosis.

The keys in Section 3.2 are presented so that if a character not characteristic of the critical species is encountered the key provides the instruction 'reject'. Where there is doubt as to the state of the character, the user should continue through the key as if the state were as for the critical species.

Arrows on the figures illustrate particular features and are numbered to correspond to the relevant couplet in the keys.

Some larvae cannot be definitely assigned to a species and the genitalia of some male adults are difficult to distinguish. However, if pupae, pupal exuviae or adults as well as larvae or larval exuviae are collected, a definite diagnosis can always be made for the critical species, as the species that are easily confused in the different developmental stages are different.

It should always be possible to determine if a larva is likely to be of the *Trogoderma* group that includes the major pest species by looking at the setae on the tarsal claw (see Section 3.1).

3.1. Rapid preliminary identification for major pest species

This outline provides a quick alternative to working through the systematic keys (Section 3.2). It is useful for rapid screening of specimens suspected of being pest species. Where a specimen is found to be probably one of the pest *Trogoderma*, identifications can be confirmed using the full keys (Section 3.2).

3.1.1 Larvae and larval exuviae

Q1. Are hastisetae present? (Caution! they are easily rubbed off. A few almost always remain).

Q2. Do the hastisetae arise out of the main sclerotised part of the tergite?

Q3. Has the tarsal claw one long and one short seta on it?

Q4. Has the antenna 3 segments of approximately equal length?

If the answer is 'yes' to these four questions, it is likely that the specimen is *Trogoderma granarium, glabrum, inclusum* or *variabile* and warrants careful investigation.
If the answer to Q1 is 'no'; the specimen is not *Trogoderma, Anthrenocerus, Anthrenus* or other *Trogoderma*-like species. If the answer to Q1 is 'yes' and Q2 is 'no'; the specimen is probably an *Anthrenus* species. If the answer to Q1 and Q2 is 'yes' and Q3 is 'no'; it can be *Reesa, Anthrenocerus*, some Australian native and exotic *Trogoderma* and similar species. If the answer to Q1, Q2 and Q3 is 'yes' and Q4 is 'no'; it is probably a non-Australian *Trogoderma* species.

3.1.2 Pupae

Q1. Are hastisetae present on the associated larval exuvia?

Q2. Are gin traps present?

If the answer to Q1 and Q2 is 'yes'; it is probably a pest *Trogoderma* species and should be investigated further.

3.1.3 Adults

Q1. Does the beetle have a median ocellus?

Q2. Is the antennal outline smooth, with no sudden changes in size between segments?

Q3. Is the antennal fossa open at the end only?

Q4. Does the elytra have three transverse bands of pale hairs on it?

If the answer to all four questions is 'yes'; the specimen may well be *Trogoderma inclusum, variabile* or *glabrum*. If the answers to Q1, Q2 and Q3 are 'yes', but 'no' to Q4, and the specimen is brownish with no distinct elytral patterning, it may be *T. granarium*. In either case the specimen should be dissected and genitalia compared with known standards (Figures 46-71).

3.2 Detailed keys to the critical species

3.2.1 Eggs

The eggs of *T. glabrum, T. inclusum* and *T. variabile* have been figured (LeCato and Flaherty 1974). There appear to be minor differences between those of the three species. No further information is available.

3.2.2 Larvae and larval exuviae

The key given below is applicable with confidence only to mature larvae or exuviae. This is the stage most frequently encountered. Larvae of *Trogoderma* on reaching maturity may either proceed with development to adults or enter diapause. In the latter condition the larva continues to moult producing exuviae, suitable for identification. The variation of characters of the younger developmental stages has not been investigated.
3.2.2.1 Key to larvae and larval exuviae

1a Beetle larvae of length less than 20 mm. Hairy, with setae on the abdominal segments of more than one type. Caudal brush of long hairs present (particularly prominent in younger stages) .................................................. 2

b Not so ........................................................................................................... reject

2a Hastisetae (Figures 2,3) present on abdominal segments (even in heavily worn specimens a few hastisetae usually remain) .............................................................. 3

b Hastisetae absent .......................................................................................... reject

3a Hastisetae arising on sclerotized dorsal surface of caudal segments. (Hastisetae usually not convergent over the cauda) ........................................................................... 4

b Hastisetae arising from the intersegmental membrane on the caudal segments (Figure 4). (Anthreni, some Trogoderma-like spp.) .............................................................. reject

4a Head of hastiseta not more than 3 times as long as the width at the widest point (Figure 3) .............................................................................................................. 5

b Head of hastiseta at least 3 times as long as the width at the widest point (e.g. Figure 5). (Anthrenocerus etc.) .......................................................................................... reject

5a Fiscisetae (Figure 6) absent ........................................................................... 6

b Fiscisetae (Figure 6) present (these are very prominent and found in all segments). (Some Australian Trogoderma spp.) .................................................................................. reject

6a Hastisetae of only one type present .................................................................. 7

b Hastisetae of two or more types (head of seta may be elongate, Trogoderma apicipenne Reitter and some other Australian endemic Trogoderma spp.) (Figure 7) .................................................................................. reject

7a Pretarsal segment of leg with 2 setae; 1 seta extending almost the length of the claw, the other about half its length (Figure 8). (Note: use of the high power of a good microscope may be required to see this feature clearly as often the two setae lie together. The short seta may then be difficult to distinguish). (This feature distinguishes pest Trogoderma from most other Trogoderma and Trogoderma-like species) .................................................................................. 8

b Setae on pretarsus both approximately of equal length. (These may both be of about the length of the claw or both much shorter than length of claw.) (Reesa vespalae, some exotic and Australian Trogoderma spp.) ........................................ reject

8a Spicisetae of 2 distinct types on the abdominal tergites (large and small) (Figure 9) .................................................................................................................. 9

b Spicisetae of the abdominal tergites all similar in length and diameter .............. reject
9a Small spicisetae present on tergites anterior to the antecostal suture (points of insertion should be visible in abraded specimens) (Figure 9). (Most Trogoderma sensu Beal key to this point) ................................................................. 10

b Small spicisetae not present on tergites anterior to the antecostal suture (some Australian Trogoderma spp.) ................................................................. reject

10a Length of apical antennal segment approximately equal to that of middle segment (Figure 10) ................................................................. 11

b Length of middle segment at least twice that of apical segment (Figure 11) reject

11a Setae of the basal segment of the antenna at least long enough to reach the apex of the middle segment when the antenna is fully extended (Figure 10) ............................................. 12

b Not so .................................................................................................................. reject

12a Epipharynx with 4 distal papillae, commonly in a single cup (Figure 12) but occasionally in 2 areas (Figure 13) ................................................................. 13

b Epipharynx with more than 4 distal papillae .......................................................... 14

13a Antecostal suture very faint and incomplete or absent on 8th abdominal segment (Figure 2, the segment should be denuded of setae to see this feature well). Without greyish pigmentation on sides or around points of insertion of large spicisetae. Antennae often with seta on middle segment (Figure 15, caution - R. vespulae also has this feature) ....................................................... T. granarium

b Antecostal suture present and usually complete on 8th abdominal segment (Figure 14). Some greyish pigmentation around the points of insertion of large spicisetae. The grey pigmentation is usually present on sides and disc of terga too. No seta on second segment of antenna. ...... T. teukton

14a Antennal setae not grouped entirely on mesal side, but extending for more than half of the circumference of antenna (Figure 15) ............................................. 15

b Antennal setae grouped on mesal site of antenna and extending for less than three-fifths of the circumference of the antenna reject

15a Epipharynx with 6 distal papillae in a single cup (occasional specimens may have 5+1 or even 4+2 arrangements - dissect more than one specimen if available) ................................................................. 16

b Not so .................................................................................................................. reject

16a* A total of at least 6 small spicisetae (or points of insertion if setae have been lost) present on first abdominal tergite, posterior to the antecostal suture, but anterior to the band of large spicisetae (Figure 9) ................................................................. 17
Fewer than 6 small spicisetae present on first abdominal tergite, posterior to the antecostal suture, but anterior to the band of large spicisetae (possibly *T. irroratum*) ... reject

17a Anteriormost small spicisetae close to the midline and anterior to the antecostal suture not long enough to extend across the suture (Figure 9) ... 18

17b All small spicisetae close to the midline and anterior to the antecostal suture sufficiently long to extend across the suture (possibly *T. varium* (Matsumura & Yokoyama), Figure 16) ... reject

18a Apical segment of antenna with at least one sensory pore within the basal quarter of the segment, (Figure 17) in many cases with the margin of the pore touching the basal margin of the segment ... 19

18b No sensory pores within the basal quarter of the apical segment of the antenna (Figure 18) ... *T. variabile*

19a Large spicisetae, close to the midline of the first abdominal segment, either smooth or clad only with inconspicuous scales and with tips smooth for the length of at least 4 times the diameter of the setae (Figure 9) ... *T. inclusum*

19b Large spicisetae, close to the midline of the first abdominal segment clad with conspicuous scales, extending to close to the tip of the seta (e.g. Figure 16) (possibly *T. irroratum*) ... reject

Notes on key to larvae and larval exuviae

Specimens which are keyed out to couplet 10 are within the genus *Trogoderma sensu* Beal. None of the known larvae of Australian endemic *Trogoderma* and *Anthrenocerus* reach this couplet, as they always have two setae of equal length on the tarsal claw and most of them have no spicisetae anterior to the antecostal suture. Couplet 7 eliminates *Reesa vespushiae* as it has two tarsal setae of equal length, almost as long as the claw. *R. vespushiae* is otherwise deceptively similar to pest *Trogoderma* species.

The separation of the larvae of critical species from the other *Trogoderma* is difficult. The key provides characters which lead to conclusive identification of *T. granarium* and *T. glabrum*, but a firm diagnosis cannot be made of *T. variabile* or *T. inclusum* on the basis of one or two larvae. The range of variation of larvae of these species is sufficiently broad to overlap with that of the closely similar species, *T. irroratum* and *T. varium*. The latter species are not widespread, recorded from Egypt and Japan respectively, and are unlikely to be encountered, but the apparent distribution may in part be due to incorrect identification. Table 2 gives the characters for members of the *inclusum* group, for couplets except 14, beyond couplet 11. The critical species belong to this group.

* Couplets beyond this point are not definitive, but represent a likely diagnosis only.
Table 2 Characters of larvae of the *inclusum* group as assessed by the key to larvae.

<table>
<thead>
<tr>
<th>Species</th>
<th>Couplet 12/15</th>
<th>13</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>glabrum</em></td>
<td>12a</td>
<td>13b</td>
<td>16a</td>
<td>17a/b</td>
<td>18a/b</td>
<td>19a</td>
</tr>
<tr>
<td><em>granarium</em></td>
<td>12a</td>
<td>13a</td>
<td>16a</td>
<td>17a</td>
<td>18a</td>
<td>19a</td>
</tr>
<tr>
<td><em>inclusum</em></td>
<td>15a</td>
<td>13b</td>
<td>16a</td>
<td>17a</td>
<td>18a</td>
<td>19a</td>
</tr>
<tr>
<td><em>irroratum</em></td>
<td>15a</td>
<td>13b</td>
<td>16b</td>
<td>17a</td>
<td>18b</td>
<td>19a/b</td>
</tr>
<tr>
<td><em>teukton</em></td>
<td>15a</td>
<td>13a</td>
<td>?</td>
<td>?</td>
<td>18a</td>
<td>?</td>
</tr>
<tr>
<td><em>variabile</em></td>
<td>15a</td>
<td>13b</td>
<td>16a</td>
<td>17a</td>
<td>18b</td>
<td>19b</td>
</tr>
<tr>
<td><em>variurn</em></td>
<td>15a</td>
<td>13b</td>
<td>16a</td>
<td>17b(?)</td>
<td>18a/b</td>
<td>19b</td>
</tr>
</tbody>
</table>

a/b = couplet does not discriminate, either because variation spans both character states or it is insufficiently precise.

Any specimen keying to couplet 16 should be taken as *T. inclusum* or *T. variabile* for quarantine purposes unless there is positive evidence to the contrary. *T. irroratum* is usually separated from *T. inclusum* and *T. variabile* by the absence of small spicisetae on the disk of the first abdominal tergite anterior to the row of large spicisetae (couplet 16a) (Beal 1960). However some specimens from the Pest Infestation Control Laboratory cultures of *T. irroratum* do have more than six and occasionally specimens of both *T. inclusum* and *T. variabile* have fewer than six. Specimens of *T. variurn* are separated from *T. inclusum* and *T. variabile* on the basis of couplet 17, but, if one of the anterior most spicisetae anterior to the antecostal suture is shorter than usual, it may not reach across the suture. Under such conditions, the other spicisetae there will cross the antecostal suture with about two-thirds their length posterior to the suture (Figure 16). The shape of the large spicisetae of *T. inclusum* is usually distinctive (couplet 19) but occasionally small scales may be present towards the ends of these spicisetae, thus giving an appearance similar to those of *T. variabile* or *T. variurn*. Occasional specimens of *T. variabile* have the lowest pore in the apical antennal segment within the basal quarter (couplet 18), though in such cases it still does not touch the basal membrane.

Peacock (1993) illustrates the setation pattern on the first abdominal tergite of each of the critical species and also figures the shape of the hastaseta of each. These are claimed to be distinctive, but his key does not take closely similar non-UK species into account.

A conclusive identification of *T. inclusum* or *T. variabile* can be made using a combination of both larval and pupal or adult characters. *T. granarium* and *T. glabrum* can also be conclusively separated using a combination of characters.
3.2.3 Pupae

No key to pupae is given here, as the range of variation is not adequately known.

All Australian *Trogoderma* pupae known, and those of *R. vespulae*, lack the structures known as gin traps (Hinton 1946) on the dorsal surface of the pupae, but these are present in the critical species. They are also found in many other *Trogoderma* spp. (Beal 1954, 1964), but are absent in *T. grassmani* Beal and *T. angustum* Solier. There are three gin traps on the pupae. Each consists of a transverse groove in the dorsal surface. The pit of the trap contains a number of spines and the lip of the trap has characteristic sclerotisation. The central gin traps of the pupae of the critical species and some other *Trogoderma* are in Figures 19-26. The morphology of these features are clearly distinctive, but in most cases do not add substantially to the separation achievable with larval characters. However, the gin trap of *T. irrortatum* has a distinctive outline to the posterior edge of the base of the pit (Figure 23), a feature which distinguishes this species from the otherwise closely similar species, *T. variabile* and *T. inclusum*.

Beal (1954) gives the number of setae in the posterior depression of the central gin trap of *T. glabrum*, *T. inclusum* and *T. variabile* as 34-40, 48-65 and 20-34 respectively. In all cases, the specimens of these particular species examined in preparation for this paper had fewer setae there than stated by Beal. The cause of this discrepancy is not known.

3.2.4 Adults

The key given below is designed to provide efficient identification of the critical species only. If the specimen under scrutiny does not key out as one of the critical species it may be treated by the key to adult *Trogoderma* species given in Appendix 1 or may be identified by the morphology of the genitalia illustrated below (Figures 46-71).

Matthews (1985) gives a key to most Australian *Trogoderma*-like genera and Peacock (1993) gives a useful illustrated key to UK derestid genera, which includes most of those found in Europe.

Female specimens of the same species tend to be larger than the males. Females also tend to have a shorter final segment to the antenna than males.

3.2.4.1 Key to adults

1a Beetles of length 1.5-4.5 mm ..................................................................................................2

b Beetles larger than 4.5 or smaller than 1.5 mm .....................................................................reject

2a Median ocellus present (Figure 27) (Derestidae) .................................................................3

b Median ocellus absent .............................................................................................................reject

3a Apical segment of hind tarsus much longer than penultimate segment (Figure 28) ..................................................................................................................4

b Apical segment equal to or shorter than penultimate segment ..............................................reject
Elytra, head and pronotum clothed with hairs ........................................5
Elytra, head and pronotum clothed with scales (Figure 29) (Anthreni) ........reject
Elytra clothed with fine hairs. These may be largely brown or black.
If black, white or whitish hairs are also present (Figure 30) ......................6
Elytra clothed with coarse black hairs only (some Australian Trogoderma) ....reject
Posterior margin of antennal cavity well-defined (carinate) for about one-half to
seven-eights of its length only, leaving the cavity open at its lateral end
(e.g. Figure 31) ....................................................................................7
Posterior margin of cavity either indistinct (Megatoma) or well-defined but
completely enclosing the cavity (Figure 32) (Anthrenocerus and others) ........reject
Spines on outer margin of fore tibia weak and straight (Figures 27 and 33) ....8
Spines on outer margin of fore tibia strong, stubby or curved (e.g. Figure 34)
(Phradonoma, some Australian Trogoderma) ........................................... reject
Terminal segment of antenna not more than 2.5 times the combined length of
the preceeding two segments. Width of terminal segment not greater than width of
penultimate segment .................................................................................. 9
Terminal segment elongated (greater than 2.5 times length of preceeding two
segments) and/or much wider than proceeding segment (Figure 29) ............ reject
Outline of antennal club smooth without sudden changes in width
(e.g. Figure 31). (Trogoderma sensu Beal. Specimens keying to this point, but
found not to be of the critical species may be identified using their genitalia or
characters given in Appendix 1) ............................................................... 10
Antennal club forming abruptly (Figure 32) ............................................ reject
Antennae with eleven segments ................................................................ 11
Antennae with fewer than eleven segments .............................................. 12
Segments of antennae approximately symetrically placed on antennal stem .... 13
Antenna serrate, flabellate and/or with segments placed asymetrically
on antennal stem (e.g. Figure 35) ............................................................. reject
Female insects with antennal club of 2-3 segments; the apical segment
sometimes having a slight fold in it. (This is caused by fusion of the apical and
subapical segments of a normally 3 segmented club (Figure 36)) .................. 15
Female insects with an antennal club of 4 or more segments,
or male insects ....................................................................................... reject
13a Length to breadth ratio of beetle less than 2.0 ........................................... 14

b Length to breadth ratio greater than or equal to 2.0 ...................... reject

14a Antennal fossa smooth or vaguely striate beneath antenna, with setae laterally (Figures 31 and 37) .............................................................. 15

b Antennal fossa microgranulate or reticulate (e.g. Figure 32) .................. reject

15a Pale hairs on the elytra forming a 3-banded transverse pattern (Figure 30) .......... 16

b Pale hairs on the elytra, if present, scattered on forming a definite pattern of other than 3 transverse bands ........................................ 18

16a Elytra largely black, with or without a dark brown patch on the outer posterior margin. Brown and dark brown longitudinal lines sometimes visible with transmitted light but not forming a well-defined pattern of light and dark bands ........................................ 17

b Elytra with a well-defined pattern of dark areas and lighter-coloured bands (e.g. Figure 38) ............................................................... 21

17a Male antennal club 5-6 segmented (Figure 39). Female antennal club 4 segmented (Figure 40) .................................................. T. glabrum

b Antennal club not so ................................................................. reject

18a Pale hairs on elytra, if present, scattered and not forming a pattern of bands ................................................................. 19

b Pale elytral hairs forming a pattern of one or more bands .................. reject

19a Elytra unicolorous or with an ill-defined mottled pattern (Figure 41). Usually light brown .......................................................... 20

b Elytra with a definite pattern of light and dark areas .......................... reject

20a Male antennal club 4-5 segmented (Figure 42). Female club 3 segmented (Figure 31) or as Figure 36 (q.v.) .............................. T. granarium

b Antennal club not so ................................................................. reject

21a Inner margin of eye distinctly notched (emarginate) (Figures 27 and 37) .......... T. inclusum

b Inner margin of eye straight, evenly curved or sinuate .......................... 22

22a Anterior and central transverse pale bands in the elytral pattern not joined by longitudinal pale bands (Figure 43) .................. 23

b Anterior and central transverse pale bands in the elytral pattern joined by one or more pale, longitudinal (admedian) bands (e.g. as Figure 38) ............... reject
Male insects with an antennal club of 6-7 segments (Figure 44).
Female insects with an antennal club of 4-5 segments (Figure 45)........... T. variabile

Notes on key to adults

*Trogoderma* species exhibit considerable variation in size, colouration and patterning. This must be borne in mind while using the key. The identifications produced with it cannot be taken as conclusive, particularly for the most variable species, *T. variabile*. Notably *T. varium* is not distinguished definitely from *T. variabile* except by couplet 23. In all cases, confirmation of diagnosis is advisable, using the distinctive (Green 1979) morphology of the male or female genitalia. These are illustrated in Figures 49, 50, 52, 57, 63, 64, 66, 71 for *T. glabrum*, *T. granarium*, *T. inclusum* and *T. variabile*.

The antennal characters are important for the separation of the various species considered here but require care in use. Because the outline of the antenna in *Trogoderma* is smooth it may be difficult to decide at what point the antennal club begins. This is particularly so with female antennae. For instance, the female antenna of *T. granarium* is often regarded (e.g., Hinton 1945, Beal 1956, but not Howe and Burges 1956) as being of 3 segments but the difference between this and the 4 segmented antennal club of species such as *T. glabrum* is difficult to appreciate without experience (see Figures 31 and 40) and is a matter of personal judgement. Because of this possible ambiguity, users of the key are advised to count the number of segments of the club of some named specimens and compare their observations with the number given in this key. If the expected and observed counts differ this should be taken into account.

The key up to couplet 10 is designed to exclude dermestid genera other than *Trogoderma sensu* Beal (1954). However, as noted above, the genus *Trogoderma sensu lat.* is in need of study and many, if not all, of the Australian species at present placed in *Trogoderma* are likely to be removed from the genus when it is revised. Because of the heterogeneity of the present group, many Australian *Trogoderma* spp., such as the common *T. apicipenne*, will be excluded prior to couplet 10. There is an apparent redundancy in some couplets prior to couplet 10. This has been put in to prevent members of unrecognised or undescribed genera from being keyed out as *Trogoderma*: an important consideration when many Dermestidae, particularly the large Australian fauna, are so little known.

Any specimen which is keyed out to couplet 14 can be taken to be within the genus *Trogoderma sensu* Beal and possibly an economically important species. If not one of the four species, specifically considered here, it may be identified using the key of Varshalovich (1975) (see Appendix 1).
3.2.4.2. Additional characters, necessary for conclusive identification of adults

General characters

In all cases where a conclusive identification is required, it is necessary to examine the genitalia. These are distinctive for both males and females. The differences between species are best appreciated in the light of experience rather than by detailed description as the differences are relatively slight in some cases, although apparently constant. Isolated male genitalia and the paired sclerites from the bursa copulatrix of the female are illustrated in Figures 46-71.

In male genitalia, the shape of the bridge of the phallobase provides most diagnostic information. This may be straight, curved or thickened in various ways depending on the species. The length and shape of the aedeagus is also important. The shape of the tenth or ring segment has been used as a character, but the shape is at least partly dependent on the presentation and distortion produced in preparing a slide mount.

The number, shape and distribution of the teeth on the paired sclerites of the female genitalia are important diagnostic features.

Characteristic features for particular species

T. granarium

*T. granarium* is normally easily recognised by its lighter brown colour and absence of definite light and dark pattern in either the setation or pigmentation of the elytra. However in some cases a distinct maculation can be seen, although not forming the pattern of bands and loops as in *T. inclusum*. The elytrial hairs are easily removed by abrasion and can be completely absent from old specimens.

The Australian species *T. singulare* Blackburn and *T. meyricki* Blackburn are superficially similar to *T. granarium* but may be differentiated from it by antennal characters and, presumably, the morphology of the genitalia.

Males of *T. granarium* are distinguished from those of many other *Trogoderma* species by the possession of a fringe of moderately stout, sub-erect hairs near and more or less parallel to the apical margin of the 5th abdominal sternite (Hinton 1945). The mentum of *T. granarium* is said to be distinctive (Howe and Burges 1956, Zhantiev 1965) but requires a difficult dissection of the mouthparts to observe. The range of variation in shape overlaps with that of other species. For instance, the shape of the anterior margin and emargination of the mentum of *T. inclusum* occasionally approaches that normally found in *T. granarium*. The anterolateral metastemal process of *T. granarium* is rounded, rarely with a rudimentary nipple present. This is said (Okumura 1966) to differentiate the species from all other *Trogoderma* occurring in the Nearctic region that have a fully developed nipple or a pyramidal shape to the process. Again, there is a degree of variation which does not allow conclusive use of this character. The distal margin of the first periphallic tergite is almost straight in *T. granarium*, but in *T. inclusum* may be rounded, pointed or emarginate (Beal 1954, Okumura and Blanc 1955). The use of the shape of the first periphallic tergite as a character appears redundant as the genitalia themselves are normally diagnostic.
T. glabrum

Many Trogoderma spp. have a pattern of light and dark bands in the elytra. *T. glabrum* usually has unicolorous and black elytra, occasionally with vague brownish areas on the apical margins of the elytra (Beal 1954, 1956). Ill-defined longitudinal striations may be visible in transmitted light. With the exception of *T. teukton*, the lack of pattern on the elytra distinguishes *T. glabrum* from other Nearctic and Palearctic species. These either have brown or black elytra or are distinctly patterned. The elytra of *T. teukton* are black, but with reddish or light brown patches on the elytra corresponding to the areas of light coloured setae. The areas below the fasciae in *T. glabrum* are black. *T. teukton* can also be distinguished from *T. glabrum* by the pattern of setation on the posterior margin of the ring segment of the male genitalia (Varshalovich 1975). The shape of the antennal cavity of the males is said to be distinctive (Beal 1956). Many Australian *Trogoderma* species are superficially similar to *T. glabrum* having dark unicolorous elytra and pronotum. However, even the most closely similar species, *T. frater Arrow*, *T. funestrum* Reitter and *T. consors* Arrow, may be distinguished by their antennal shape, the coarseness of the elytral setation and the lack of the three transverse bands of light coloured hairs (fasciae) on the elytra.

T. inclusum

*T. inclusum* is immediately distinguished from other *Trogoderma* associated with stored products by the emarginate inner edge of the eye. *T. teukton* may have shallowly emarginate eyes (Beal 1954) but the eye margin of the eyes in the other species is either straight or sinuate. The elytral pattern is also distinctive having a longitudinal light-coloured band joining the basal and central bands of light pigmentation. This separates the species from *T. variabile* and *T. teukton* and from the closely similar *T. varium* with which it can interbreed. The elytral pattering and presence of 3 bands of fasciae distinguish *T. inclusum* from all known Australian *Trogoderma*, although the patterning of *T. froggatti* Blackburn could be mistaken for that of *T. inclusum* before detailed examination. *T. froggatti* has distinctive antennae and only a single band of light coloured elytral hairs. Also, male *T. froggatti* has asymetrically placed segments on the antennal stem, and both male and female have a somewhat more clubbed antenna, lacking the smooth outline and progressive change in size of the segments found in most *Trogoderma*.

*T. inclusum* has been confused nomenclatorially with *T. versicolor* in the early American and English literature. There is only slight resemblance between the two species and they are adequately separated in the key.

T. variabile

The elytral pattern of light and dark cuticular areas is variable in this species. The range of variation has been figured by Beal (1954) (as *T. parabile*). It may sometimes be reduced to 3 well-separated light patches or even a single band towards the apex of the elytron. Alternatively, the light areas may be extended. However, in all cases the basal light area is not joined in the central band or network. A similar pattern is found on *T. varium* and sometimes *T. teukton*, but not *T. inclusum*. Both *T. varium* and *T. teukton* may be distinguished from *T. variabile* characters on the genitalia (see Figures 57, 58, 69, 70, 71) and the shape of the antennae. The colour of the setation on the pronotum of *T. variabile* is largely golden brown whereas more than half the hairs on the pronotum of *T. teukton* are whitish (Beal 1954). No Australian *Trogoderma* spp. so far described have the elytral pattern of 3 bands of fasciae. *T. froggatti* may be confused with *T. variabile* as with *T. inclusum* at first glance.
3.2.4.3 Genitalia of *Trogoderma* species

The shape of genitalia with few exceptions is distinctive for each species of *Trogoderma*. Examination of these structures provides an easy method of distinguishing otherwise closely similar species and, in some cases (e.g. between *T. variabile* and *T. variatum*) may provide the only diagnostic characters which can be used with confidence. Photographs of male genitalia (Figures 46-59) and the sclerites of the bursa copulatrix of the females (Figures 60-71) are given here. The illustrations cover most of the *Trogoderma* species found associated with stored products. *T. okumurai* Beal and *T. cavum* Beal were not available for study, but the male genitalia have been figured (Beal 1964, 1982). No specimens of male *T. teukton* were available for study. However, Beal (1956) states "the bridge of the phallobase in *teukton* is even, narrow and slightly arcuate." The genitalia (male and female) of *T. bactrianum* Zhantiev and *T. ornatum* Say are given in Appendix 1.

**Male genitalia**

The male genitalia shown in Figures 46, 47, 49-59 are mounted on flat microscope slides and have suffered some compression. This separates the claspers slightly but may also distort the aedeagus where it is a long curved structure (as in *T. inclusum*). Figure 48, of *T. apicipenne* male genitalia, is taken of a mount in a cavity slide as the structure is too deep and narrow to be mounted flat as the other specimens.

The complete terminalia of *T. sternale* Jayne are shown in Figure 56. Mounting in this way without further dissection preserves the other sclerites apart from the true genitalia. The forms and setation of other sclerites have been used as diagnostic characters (see Appendix 1) and it may be preferable to mount the male terminalia thus, rather than dissecting the structures to isolate the genitalia, as is more usual.

It is clear from Figures 46-59 that there is a wide range of variation in the shape of the structures in the male genitalia. In most cases the shape of the bridge of the phallobase and the ratio of its width to that of the aedeagus provides a diagnostic features for particular species. The shape and width of the bridge of *T. glabrum* (Figure 49) and *T. granarium* (Figure 50) separate these species from all others. *T. inclusum* (Figure 52) is distinguished from *T. irroratum* (Figures 53 and 54) and *T. variabile* (Figure 57) by the shape of the base of the genitalia. The width of the bridge of *T. irroratum* is similar to that of *T. inclusum* and narrower than that of *T. variabile*. The curvature of the bridge of *T. irroratum* is dependent on the exact presentation on mounting and thus cannot be used as a character (c.f. Figures 53 and 54). The genitalia of *T. variatum* (Figure 58), and particularly the shape of the bridge of the phallobase, are distinctive.

**Female genitalia**

Only the bursa copulatrix and its structures were investigated here in detail. The sclerites of the bursa copulatrix in almost all cases provide easily distinguishable diagnostic characters to all species of *Trogoderma* examined. *T. sternale*, *T. anhrenoides* and some unidentified Australian species lack sclerotised structures in the bursa copulatrix. The wall of the bursa copulatrix of *T. anhrenoides* is distinctively covered with small tubercules (Figure 62), but there are no paired sclerites present. The sclerites of *T. irroratum*, *T. variatum* and *T. granarium* differ only slightly, with those of *T. irroratum* being somewhat longer and with a greater number of teeth. *T. variatum* and *T. granarium* are clearly distinguished on other grounds.
T. apicipenne, an Australian species, has three sclerites (Figure 61), a unique feature. Other endemic Australian species examined have not had any sclerites in the bursa copulatrix. There is only a single sclerite in that of T. grassmani Beal and the bulb of the spermatheca is unusual, being pigmented or more heavily sclerotised than in other Trogoderma.

It is clear that on the basis of a combination of general morphology and that of the bursa copulatrix, a single female specimen of one of the critical Trogoderma may be unambiguously identified.

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5. REFERENCES


Fig. 2. Dorsal view of abdominal segments of larva of *T. granarium*. Right side denuded to show absence of antecostal suture of 8th segment.

Fig. 3. Head of hastiseta, *T. variabile*. 
Fig. 4. Dorsal view of abdominal segments of larva of *Anthrenus flavipes* Le Conte with right side denuded.

Fig. 5. Head of hastiseta, *Anthrenocerus australis*. 
Fig. 6.
Setation of posterior abdominal segments of an endemic Australian species, *T. carteri*, showing fiscisetae.

Fig. 7.
Dorsal view of larva of *T. apicipenne*, showing two types of hastisetae.

Fig. 8. Tarsal claw of larva of hind leg of *T. granarium*. 
Fig. 9. Central region of 1st abdominal tergite of larva of *T. inclusum*.

Fig. 10. Lateral view of antenna of larva of *T. inclusum*. 
Fig. 11. Head of larva of *Anthrenocerus australis*, showing elongate second segment to antenna.

Fig. 12. Scanning electron micrograph of the fringe of the labrum and distal part of the epipharynx of larva of *T. granarium*.
Fig. 13. Optical micrograph of the epipharynx of *T. granarium* showing the unusual fragmentation of the distal epipharyngeal papillae.

Fig. 14. Dorsal view of abdominal segments of larva of *T. glabrum* with right side denuded.
Fig. 15. Antenna of larva of *T. inclusum* showing arrangement of setae on basal segment. (Note the possession of a seta on the second segment is unusual in this species.)

Fig. 16. Central region of 1st abdominal tergite of larva of *T. varium*.
Fig. 17. Ventral view of antenna of larva of *T. inclusum*, showing positioning of sensory pores on the apical segment.

Fig. 18. Ventral view of antenna of larva of *T. variabile*, showing positioning of sensory pores on the apical segment.
Fig. 19 - 22.
Dorsal view of central pupal gill-traps of (19) T. anthrenoides, (20) T. granarium and (21) T. glabrum, (22) T. inclusum.
Fig. 23 - 26. Dorsal view of central pupal gnathos of (23) T. irroratum, (24) T. simplex, (25) T. stramine and (26) T. vanable.
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Fig. 30. Right elytron of *T. glabrum* (male) under incident light.
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Fig. 32. Antenna and antennal cavity of *Anthrenocerus australis* (male).
Fig. 33. Foreleg of *T. granarium* showing tibial spines.

Fig. 34. Foreleg of *Phradonoma tricolor* Arrow (male) showing tibial spines.
Fig. 35. Lateral view of an unidentified Australian *Trogoderma* (male) showing flabellate antenna with segments asymmetrically placed on the antennal stem.

Fig. 36. Antenna of *T. granarium* (Female) showing condensation of 3 antennal segments, giving an 8-jointed appendage.
Fig. 37. Antenna, eye and antennal cavity of *T. inclusum* (male).

Fig. 38. Elytron of *T. varium* in transmitted light.
Fig. 39. Antenna, eye and antennal cavity of *T. glabrum* (male).

Fig. 40. Antenna, eye and antennal cavity of *T. glabrum* (female).
Fig. 41. Elytron of *T. granarium* in transmitted light.

Fig. 42. Antenna, eye and antennal club of *T. granarium* (male).
Fig. 43. Typical elytral pattern of *T. variabile*.

Fig. 44. Antenna, eye and antennal cavity of *T. variabile* (male).

Fig. 45. Antenna, eye and antennal cavity of *T. variabile* (female).
Figs. 60-71. Sclerites of the bursa copulatrix of female Trogoderma spp. All to same scale except Fig. 62 which is reduced by 2x. (60) T. angustum, (61) T. apicipenne, (62) T. anthrenoides, (63) T. glabrum, (64) T. granarium, (65) T. grassmani, (66) T. inclusum, (67) T. irroratum, (68) T. simplex, (69) T. teukton, (70) T. varium and (71) T. variabile.
Appendix 1

Key to adults of the genus Trogoderma associated with stored products

The key below is a translation of that of Varshalovich (1975), rearranged into a dichotomous form and edited slightly in places where the meaning was apparently unclear. It covers the adults of all Trogoderma species known to be found in association with stored products, with the exception of T. varium, T. irroratum, T. anthrenoides, T. okumurai, T. cavum and the endemic Australia Trogoderma species. The illustrations are taken from Varshalovich (1975), who appears to have redrawn them from the original sources. They have been retouched for reproduction.

T. varium and T. irroratum may be distinguished and identified using the main key. The genitalia of T. anthrenoides (Figures 47 and 62) are distinctive. Specimens of T. okumurai were not available for study. The genitalia have been illustrated (Beal 1964). The adults are otherwise indistinguishable from T. grassmani. Beal (1982) describes features of T. cavum. It is close in form to T. megatomoides Reitter.

Specimens which are analysed to couplet 11 of the main key (Section 3.4) to adults can be treated further with the key in this Appendix.

1a Upper part of the body downy with monochromatic hairs. The elytra are dark brown and without maculation. .................................................. 2

b Dorsum is clothed with the hairs of 2 or 3 colours (it must be borne in mind that the vestiture of T. granarium and some other species may be abraded or slightly faded.) .................................................. 3

2a The elytra densely clad with hairs. Antennal club of female, compact. Segments of the antennae of the males are connected slightly eccentrically (Fig. D.1); in the females only some of the antennal segments are joined eccentrically. The 8th tergite of the male genitalia is shown in Figure H.8 ........................................... Trogoderma sinistrum Fall.

b The elytra are clothed with semi-contiguous hairs. The antennal club of female not compact, but with each articulation having a more or less distinct petiole. The antennae of the male are flabellate and those of the female are crestate (Fig. D.2) ........................................... Trogoderma balfinchae Beal

3a Elytra with only a single light-coloured, translucent central band. The base of the elytra is rarely a lighter colour than the remainder ........................................ 4

b Elytra completely without light patterns on the cuticle or with more than one translucent band or vestiges of 3 bands formed only of light coloured hairs ........... 5

4a Antennae of male flabellate (Fig. D.3) and those of the female, crestate. Punctations of the pronotal disc separated from each other by a distance of one-quarter to three-quarters of their diameter. Antennal sockets completely enclosed by a knife-like carina. The position of the light coloured band on the elytra is shown in Fig. B.1 ........................................... Trogoderma fasciferum Blatch.
Antennal joints of both sexes only slightly eccentric. Each articulation has a short petiole at its base (Figs. D.4, D.5). Punctations of the disc of the pronotum continuous. The antennal cavity is not completely closed at the rear. A thin, low, almost sharp carina is distinctly visible only along the latter third of the rear diagonal edge and on the first (basal) and third (upper), it is indistinct. The normal elytral pattern is shown in Fig. B.2. The male genitalia (8th tergite and phallobase) are shown in Fig. G.10 and H.3. ........................................... *Trogoderma primum* Jayne

Body elongate and narrow. The ratio of its width to the base of the elytron to its length (pronotum and elytra) is greater than 2.1. Antennal cavities not completely closed at the rear. The low, almost sharp carina is distinct only for the basal two-thirds, but in the remaining one-third it does not extend to the lateral margin of the pronotum. The light-coloured setation on the light areas of the elytra consists almost entirely of white hairs, but among these are scattered individual light golden-brown hairs. The normal elytral pattern is as shown in Fig. B.3. *Trogoderma angustum* Solier

Body comparatively short. The ratio of its width to the length is less than 2:1. Antennal cavities more or less completely enclosed behind the sharp diagonal marginal carina. Cuticle of the elytra with light coloured translucent areas in the form of bands, or, if such areas are lacking, uniform in colour. The light coloured hairs on the maculation of the elytra usually have a considerable admixture of hairs of a different colour................. 6

Base of the antennal cavities heavily punctate on all surfaces with the exception of a small smooth area close to the anterior edge. The punctations are 2 to 3 times as large as the facets of the eyes. Antennal club of the female has 5 to 6 segments. The male genitalia are shown in Figs. G.4 and H.7.............. *Trogoderma simplex* Jayne

Base of the antennal cavities either dotted with small punctations, the size of which, as a rule, is equal to the size of the facets of the eyes, or shiny with small striations. Antennal club of the female has 3 to 4 segments with the apical segment of the club occasionally elongated.............................................................. 7

Cuticle of the elytra uniform in colour, light reddish brown without a definite pattern, occasionally with a scattering of faintly discernible greyish spots. There may be indistinct dark spots on the pronotum, or else it may be completely black. On the upper part of the body, among the yellowish hairs, there are dark areas of the cuticle covered with light brownish hairs (Fig. A.6). The number of antennal joints varies from 9 to 11. The antennal club of the male consists of not more than 5 segments (Fig. D.6). The antennal club of females consists of 4 segments (Fig. D.7), and rarely, in the case of fusion of 2 upper segments, of 3 segments. In the male, near the posterior edge of the fifth visible sternite, there is a small fringe of very thick dark hairs. The central projection of the posterior edge of the pronotum in the male is without a carina (Fig. F.12). In the female there is occasionally a pronounced protuberance on the upper side (Fig. F.13). The antennal cavities are open (Fig. F.9). The serrated sclerites in the female genitalia are small, slightly sclerotized and in length they are usually equal to the length of the corrugated section of the spermatheca (Fig. T.12). The male genitalia are shown in Figs. H.4 and J.1. The sclerite of the mentum of both sexes has a deep recess the anterior edge and has curled hairs on the margins (Fig. G.1). The length of the body of the male is 1.8 mm and the female is about 3.0 mm. ........................................... *Trogoderma granarium* Everts (syn. afrum Priesn.; khapra Arr.)

.................................................. (syn. afrum Priesn.; khapra Arr.)
Elytra with a clear pattern which may be formed either by variations in the thickness of the cuticle or hairs of a different colour or by both methods. (It must be borne in mind that in some species, e.g. *T. ornatum*, the pattern may be faint and indistinct). The antennae always have eleven segments. The antennal club of the male is not less than 5 segments and the antennal club of the female not less than 4 segments.

The elytra are uniformly coloured; either black (or dark brown in incompletely coloured specimens) or black with indistinct brownish regions only on the shoulders or the upper margin of the elytra. Occasionally having 3 translucent bands (basal, median and apical). There may also be areas covered with light coloured hairs.

Cuticle of the elytra of 2 colours, i.e. it has a translucent pattern in the form of 3 (i.e. basal, median and apical bands or regions) or only 2 bands (median and upper) or regions.

The antennal club of the males is serrate and fairly loosely jointed. That is, each of its segments is connected to the adjacent one by its own short petiole (as in *T. sternale*, cf. Fig. E.8, E.9).

Antennal club of the male compact and symmetrical (Fig. D.10).

The antennal club of the male has 8 segments (Fig. D.8), that of the female 4 segments (Fig. D.9). The antennal segments have distinct petioles which are not connected eccentrically. The antennal cavities are open. The central projection of the posterior edge of the pronotum has no carina. The body is elongate and oval in shape, the ratio of the width through the shoulders to the length (pronotum and elytra) is 1:2.1 to 1:2.2. *Trogoderma megatomioides* Reitt.

The antennal club of male has 5 segments and that of female, 4 segments. Antennal segments connected eccentrically with slightly visible petioles. Antennal cavities closed. The central projection of the posterior edge of the pronotum has a carina. The body of the beetle is short and oval; the ratio of the width to the length being 1:1.8 to 1:1.98. *Trogoderma paralia* Beal

Antennal club of the males (Fig. D.10) with 9 segments, i.e. a considerable broadening begins from the 4th segment. The upper segment is conical and slightly pointed at the apex. Its length is one-quarter that of the total length of the 9th and 10th segments. The antennae of the female areas in Fig. D.11. The mentum has a deep wide depression, half-way to the anterior edge and almost straight side edges. According to Zhantiev (1970) the anterior edge of the mentum is straight. Floor of the antennal cavities, bare, shiny and in parts dull, with oblique striations. The general position of maculation and bands of light coloured hairs on the uniformly dark brown elytra is shown in Fig. B.4. Occasionally there are light brown spots on the upper surface of the elytra. The upper part of the body is covered in dark light hairs. The ratio of the body width of the beetle to its length varies from 1:1.60 to 1.75. The body length is 2.0-4.0 mm. *Trogoderma glabrum* Herbst (syn. *nigrum* Herbst; *boron* Beal).
Antennal club of the female (Fig. D.12) with 5 segments, i.e. a pronounced widening begins from the 7th segment. The apical segment is conical, tapering to the end and its length is one-third greater than the total length of the 9th and 10th segments. The antenna of the female is shown in Fig. D.13. The open area of the base of the antennal cavities of the male is narrow and the floor of the cavities has a few indistinct striations (Fig. F.1). The female genitalia are as in Fig. J.8. The male genitalia are as in Fig. F.6 and J.5 \textit{Trogoderma longisetosum} Chao & Lee. \(\ldots\) (syn. \textit{glabrum} Chao & Lee, nec \textit{glabrum} Herbst).

Elytra with only 2 translucent lighter-coloured regions in the forms of bands on the cuticle. \(\ldots\) 13

Elytra with translucent regions on the cuticle in the form of 3 bands. \(\ldots\) 14

Antennal cavities indistinct. Antennae of the male with an 8-segmented loose club. The upper segment of the club is almost egg-shaped and twice the length of the 10th segment (Fig. E.10). The position of the elytral maculation is shown in Fig. B.5 \textit{Trogoderma variegatum} Solier.

Antennal cavities distinct, wide and deep, with, in the female, a very long projection on the outer edge (Fig. F.2, F.3). The antennae are very thick with a compact club, the 3rd segment of the antennae of both sexes being slightly longer than the 4th. The antennal club of the male (Fig. E.1) has segments with the apical segment oval-shaped and broadly rounded at the end. Its length is equal to the 3 proceeding segments taken together. In the female the antennal club (Fig. E.2) has 5 segments, the upper segment of which is short and conical and half the length of the proceeding one. The male genitalia are as in Fig. I.4 and J.4. One of the serrated sclerites of the female genitalia is shown in Fig. J.11 \textit{Trogoderma laitcorme} Chao & Lee.

The basic light-coloured pattern extends from the base of the elytra to a distance of at least half the length of the elytron (Fig. B.2, B.7). The 8th tergite of the male genitalia are shown in Fig. H.1; the phallobase is as in Fig. G.8 \textit{Trogoderma grassmani} Beal.

The basic light-coloured pattern of the elytral cuticle extends close to the base, or does not extend more than half the length of the elytron. \(\ldots\) 15

The internal margin of the eyes is higher than the base of the antennae and is emarginate to a greater or lesser degree. \(\ldots\) 16

Internal edge of the eye straight or very slightly curved. \(\ldots\) 17

Eye cavity distinct. Floor of the antennal cavities shiny, with thick striations. First abdominal sternite with thick short slanting striations on the sides of the disc, extending obliquely from the internal edge of the anterior of the coxal cavities. The structure of the antennae of the female is shown in Fig. E.3. The structure of the phallobase is as in Fig. G.6 \textit{Trogoderma inclusum} Le Conte. \(\ldots\) (syn. \textit{tarsale} Wdosdl.; \textit{versicolor} Hint., Beal (nec Creutz.)).
Eye cavity indistinct. Floor of the antennal cavities dull and micro-granulate. Without fine oblique striations on the sides of the disc of the first abdominal sternite, close to the outer edge of the posterior coxal depressions. The normal elytral pattern is shown in Fig. B.14, B.15. Elongated hairs close to the inner margin of the elytra, amongst the light coloured setation. The structure of the antennae is shown in Fig. E.4, E.5. The male genitalia are as in Figs. G.5, H.5 and I.1. \textit{Trogoderma versicolor} Creutz.

17a Antennal club of the male distinctly serrate. Segments loosely joined with a distinct petiole. Basal band or loop of the elytral pattern always connected with the median band. The connecting band is sometimes slightly broadened, causing the light coloured loop to merge with the median band. \textendash; 18

17b Antennal club of the male not serrate and apical segments always more or less compact. Elytra with a very clearly marked lateral light band. The loop of median and apical bands are connected \textendash; 19

18a Third segment of the antennae of the male similar in length and width to the 2nd and 4th segments. Segments of the antennal club of the male distinctly eccentric or crestate (Fig. E.6). The antennae of the female are in Fig. E.7. The light-coloured elytral pattern consisting of fine bands with the basal loop divided by a thin light-coloured extension of the fine bands (Fig. B.8-B.10). \textit{Trogoderma ornatum} Say

18b Third segment of the antennae of the male small; in length and width equal only to half the 2nd or 4th segment. Antennae of male having an 8-segmented club of only moderately eccentric segments (Fig. E.8). Antennal of the female with a club of 5 segments (Fig. E.9). The light-coloured pattern on the elytra variable (Fig. C.1-7) and consisting only of wide or narrow lines. If the lines are narrow, the light-coloured basal loop is not divided by an extension of the light-coloured band. The phallobase is shown in Fig. G.11. The 8th tergite of the male genitalia is shown in Fig. H.6. \textit{Trogoderma sternale} Jayne

(Note: At the present time, in addition to the typical form of the species, 5 sub-species are known: \textit{Trogoderma sternale} maderae Beal (Fig. C.3); \textit{T. s. deserti} Beal (Fig. C.5); \textit{T. s. aspericole} Casey (Fig. C.5); \textit{T. s. complex} Casey (Fig. C.6); \textit{T. s. plagifer} Casey (Fig. C.2). The latter differs so markedly in the elytral pattern and also in the distribution of the setae on the body of its larva that it may possibly be subdivided into an independent species. Traces of the elongated lines close to the median band do not connect the basal loop.)

19a Elytra with 1 or 2 light-coloured long lines between the basal loop and the median band (Fig. C.9). Antennal club of male with 7 segments and that of the female 6 segments. Apical segment of the antennae of the male bluntly rounded equal in length to the 3 preceding segments together (Fig. E.11). Apical segment of the antennae of the female pointed and 1.5 times as long as the preceding segment (Fig. E.12). Mentum with a curved posterior margin and a straight anterior margin (Fig. G.2). Width of mentum 2.5-3 times greater than its length. In the male genitalia the lateral margin of the 8th tergite is smoothly curved posteriorly and with a deep semi-circular depression in the centre of the base. Uniformly sclerotised except for the lighter coloured large triangular membranous area in the posterior section of the sclerite. The hairs on the lateral margins are longer than in the middle of its anterior edge (Fig. I.2). On the posterior margin of the 9th (bulbous) segment
there are no bristles. The 10th tergite is semi-circular, and the hairs are distributed only to the rear of its posterior edge (Fig. J.6). The phallobase is shown in Fig. G.12. The serrated sclerites in the female genitalia are noticeably sclerotized, curved and 2 or 3 times as long as the corrugated section of the spermatheca (Fig. J.9). The length of the body is 2.7-5.5 mm..................................Trogoderma bactrianum Zhantiev

b Elytra without light-coloured hairs between the basal and median bands..................20

20a Antennal club of the male with 8 segments and with the apical segment bluntly rounded and equal in length to the 3 preceding ones (Fig. E.13). The antennae of the female are as in Fig. E.14. The light-coloured hairs on the pronotum are almost all golden-yellow. The normal elytral maculation is shown in Fig. B.11-13 and G.8. The 8th tergite of the male genitalia is almost semi-circular with a slight emarginate posterior edge, moderately sclerotized, and without a triangular membranous area in the median posterior section. The hairs on the posterior margin of it are uniformly distributed, different in length, being longer at the corner (Fig. H.2). The hairs on the 10th tergite are located along the whole of its posterior margin. Setae not present on the posterior angles of the 9th (bulbous) segment (Fig. J.3). The form of the floor of the antennal cavities is as in Fig. F.4, F.5. The median projection of the posterior margin of the pronotum is as in Fig. F.10, F.11. The phallobase is as in Fig. G.7 and the serrated sclerites of the female genitalia are as in Fig. J.10. Mentum 4 to 4.5 times as wide as long, with a slight depression behind the anterior margin (Fig. G.3). The length of the body is 2.0-4.6 mm..................................Trogoderma variabile Ball. ....................................................(syn. parabile Beal; persica Pic).

b Antennal club with 5-6 segments and a pointed apical segment (Fig. D.14, 15). There are at least 30% white hairs in the setation of the pronotum. The light-coloured elytral pattern may be almost completely absent so it may be taken for T. glabrum, from which it can be easily distinguished by the structure of its genitalia. The punctuation of the antennal cavities is figured in Fig. F.6, F.7. Mentum with an almost straight anterior edge, sometimes with a very small triangular section in the middle. The shape of the 8th abdominal tergite of the male is shown in Fig. I.3. The posterior margin of the 10th tergite of the male has 2 downy long hairs, the remaining hairs along the central section of the posterior tergite are short and uniformly distributed (Fig. J.2). The serrated sclerites in the female genitalia are narrow and curved in a straight angle (Fig. J.7). The length of the body is 2-5 mm..................................Trogoderma teukton Beal
Figure A.  
(1) Megatoma pubescens (Zett.), upperside; (2). M. undata ussuriensis Mroc., upperside; (3) Orphinus fulvipes (Guer.), male antenna; (4) O. fulvipes, female antenna; (5) Anthrenocerus australis (Hope), male antenna; (6) Trogoderma granarium Ev., upperside; (7) Phradonoma villosulum Duft., female upperside; (8) P. villosulum, male antenna; (9) P. villosulum, female antenna; (10) P. villosulum, fore tibia; (11) P. tricolor Arr. male antenna; (12) P. tricolor, female antenna.
Figure B. Elytral patterns of Trogoderma spp. (1) T. fasciferum Blatch.;
(2) T. primum Jayne; (3) T. angustum (Sol.); (4) T. teukton (Herbst); (5) T. variegatum (Sol.); (6) T. grassmani Beal, typical pattern;
(7) T. grassmani, expanded pattern; (8) T. ornatum Say, typical pattern;
(9) T. ornatum, Mexican pattern;
(10) T. ornatum, Texan pattern; (11) T. variabile Ball., typical pattern;
(12) T. variabile, expanded pattern; (13) T. variabile, reduced pattern;
(14) T. inclusum Le Conte, typical pattern;
(15) T. inclusum, reduced pattern.
Figure C. Elytral patterns of *Trogoderma* spp. (1) *T. sternale* Jayne; (2) *Trogoderma sternale*, typical pattern; (3) *T. sternale maderae* Beal; (4) *T. sternale deserti* Beal; (5) *T. sternale aspericole* Cas.; (6) *T. sternale complex* Cas.; (7) *T. sternale plagifer* Cas.; (8) *T. variabile* Ball.; (9) *T. bactrianum* Zhant.
Figure D. Antenna of Trogoderma spp. (1) T. sinistrum Fall. (male); (2) T. ballfinchiae Beal (female); (3) T. fasciferum Blatch. (male); (4) T. primum Jayne (male); (5) T. primum (female); (6) T. granarium Ev. (male); (7) T. granarium (female); (8) T. megatomoides Reitt. (male); (9) T. megatomoides (female); (10) T. glabrum Herbst (male); (11) T. glabrum (female); (12) T. longisetosum Chao & Lee (male); (13) T. longisetosum (female); (14) T. teukton Beal (male); (15) T. teukton (female).
Figure E. Antennae of Trogoderma spp. (1) *T. laticorne* Chao & Lee (male); (2) *T. laticorne* (female); (3) *T. inclusum* Le Conde (female); (4) *T. versicolor* Creutz. (male); (5) *T. versicolor* (female); (6) *T. ornatum* Say (male); (7) *T. ornatum* (female); (8) *T. sternale* Jayne (male); (9) *T. sternale* (female); (10) *T. variegatum* Sol. (male); (11) *T. bactrianum* Zhant. (male); (12) *T. bactrianum* (female); (13) *T. variabile* Ball. (male); (14) *T. variabile* (female).
Figure F. Morphology of antennal cavity and metasternal process of *Trogoderma* spp. (1) *T. longisetosum* Chao & Lee (male); (2) *T. laticorne* Chao & Lee (male); (3) *T. laticorne* (female); (4) *T. variabile* Ball. (male); (5) *T. variabile* (female); (6) *T. teukton* Beal (male); (7) *T. teukton* (female); (8) *T. granarium* Ev. (male); (9) *T. granarium* (female); (1) *T. variabile* (male); (11) *T. variabile* (female); (12) *T. granarium* (male); (13) *T. granarium* (female).
Figure G. Shape of mentum and male genitalia of Trogoderma spp.
(1) T. granarium Ev.; (2) T. bactrianum Zhant.; (3) T. variabile Ball.; (4) T. simplex Jayne; (5) T. versicolor Creutz;
(6) T. inclusum Le Conte; (7) T. variabile; (8) T. grassmani Beal;
(9) T. ornatum Say; (1) T. primum Jayne; (11) T. sternale Jayne;
(12) T. bactrianum Zhant.
Figure H. Shape of the periphalllic (8th) tergite of *Trogoderma* spp. (1) *T. grassmani* Beal; (2) *T. variabile* Ball.; (3) *T. primum* Jayne; (4) *T. granarium* Ev.; (5) *T. versicolor* Creutz.; (6) *T. sternale* Jayne; (7) *T. simplex* Jayne; (8) *T. sinistrum* Fall.
Figure 1. Shape of the periphallic tergite of *Trogoderma* spp. (1) *T. versicolor* Creutz.; (2) *T. bactrianum*; (3) *T. teukton* Beal; (4) *T. laticorne* Chao & Lee; (5) *T. variabile* Ball.; (6) *T. longisetosum* Chao & Lee.
Figure J. Shape of the 9th (ring) and 10th segment of male *Trogoderma* species and of the paired sclerite of the bursa copulatrix of female *Trogoderma* spp. (1) *T. granarium* Ev.; (2) *T. teukton* Beal; (3) *T. variabile* Ball.; (4) *T. laticorne* Chao & Lee; (5) *T. longisetosum* Chao & Lee; (6) *T. teukton* Beal; (7) *T. bactrianum* Zhant.; (8) *T. longisetosum* Chao & Lee; (9) *T. bactrianum* Zhant.; (10) *T. variabile* Ball.; (11) *T. laticorne* Chao & Lee; (12) *T. granarium* Ev.
Appendix 2 - Apparatus and materials used for preparation of slides of Trogoderma

1. Recipe for 'Stroyan's medium' and care of slides made with the medium (from Stroyan 1949)

A suitable water-based mountant, similar to Berlese's fluid, here called 'Stroyan's medium', can be made as follows:

Ingredients:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gum arabic, high quality lumps</td>
<td>120g</td>
</tr>
<tr>
<td>Chloral hydrate</td>
<td>200g</td>
</tr>
<tr>
<td>Glacial acetic acid</td>
<td>50mL</td>
</tr>
<tr>
<td>50% w/w glucose syrup</td>
<td>50mL</td>
</tr>
<tr>
<td>Distilled water</td>
<td>400mL</td>
</tr>
</tbody>
</table>

Procedure:

The gum is allowed to dissolve in the water by standing overnight. The mixture is gently warmed on a hot plate in a fume cupboard, while stirring with a glass rod to complete the dissolving of the gum. The other ingredients are then added in the order shown, with stirring until the mixture is clear and free of lumps. A pad of Hyflo or other filter aid is made in a 150mm ceramic filter funnel connected to a 1L Buchner flask on a water vacuum pump. The mixture is filtered while warm through the pad under vacuum. The process takes several hours and some boiling of the filtrate will occur. The filtered mixture should be left to evaporate in a dust-free environment to the point where it drops from a glass rod without forming tacky threads and just retains its demarcation when placed on a slide (exact consistency required is a matter of individual preference).

Slides prepared with Stroyan's medium need no attention unless very long storage (>10 years is required). If this is required the cured slide, more than 12 months old, should be ringed first with Euparal and then a varnish such as Murrayite.

2. Preparation of chloral-phenol (from Stroyan 1949)

To prepare chloral-phenol clearing mixture, warm together at 50°C a mixture of equal parts by weight of phenol and chloral hydrate crystals with 5% by weight of 50% w/w glucose syrup. This will give a clear, slightly pinkish fluid. Store in well stoppered dark glass bottles to prevent discolouration.

CAUTION: Phenol is corrosive and can cause burns to the skin. Eye protection should be worn when handling and making chloral-phenol and the fumes, produced when the mixture is warmed, should not be inhaled.

3. Method of producing tungsten needles for micro dissection

High quality points for micro dissection can be produced by sharpening lengths of tungsten wire electrically, using a low voltage power source. These points are not easily barbed, which is an advantage when performing extremely fine dissections.
Materials
Transformer
Primary
240 volts
0.8 amps
50 cycles
Secondary
32 volts
5.5 amps
175 watts

Carbon stick electrode
Caustic solution eg. 10% w/v potassium hydroxide solution
250mL beaker
Metal dissection needle holders
A length of two wire flex. One end of the flex has an electrical plug for attachment to the secondary outlet of the transformer. The other end is split into two separate wires to which alligator clips are attached. The carbon stick is attached to one of these wires.

Tungsten wire cut into one inch sections (To avoid splintering of the tungsten wire cut the sections using a diamond cut off wheel).

Method
Plug the flex into the transformer and turn on the power. Three parts fill the beaker with the caustic solution and place the carbon stick attached to the alligator clip into the solution in the beaker. Fit a tungsten wire length into the point holder and grip the point holder with the other alligator clip. Dip the wire into the solution repeatedly. This action removes metal ions from the wire, thus producing a point.

A number of points can be produced in one batch by placing more than one wire into the point holder splaying them so they do not touch. As hydrogen gas is given off in this process, points should be sharpened in a fume cupboard, particularly when producing more than one point at a time. Depending on the length of time wires are submerged and the number of dips into the solution, points of varying taper and sharpness can be produced.

Eye protection should be worn.
Fig. 72  Diagram showing set-up for producing tungsten needles