

COURSE CONTENTS

STORED PRODUCT PESTS AND THEIR MANAGEMENT (ENT-508)

OBJECTIVES OF COURSE

To provide concepts of stored grain pest management, storage principles and storage losses due to insects.

THEORY:

Introduction; identification, biology and management of different stored product pests; principles and types of storages; factors affecting grain and other products in storages; stored product losses and their prevention.

PRACTICAL:

Visits to different godowns and demonstration of sampling methods and estimation; collection, identification and management of different stored product pests; culture of some stored products insect pests under different climatic conditions.

BOOKS RECOMMENDED:

1. Ashfaq, M. Saleem, M. A. and Ahmad, F. 2009. Zari Agnas ki Mahfooz Zakhira Kari (in Urdu). Pak Book Empire, Lahore.
2. Hill, D.S. 2002. Pests of Stored Food Stuff and their Control. Kluwer.
3. Hill, D.S. 2002. Pests of Stored Food Stuffs and Their Control, Springer Publisher.
4. Rees, D. 2009. Insects of Stored Products. Manson Publishing Company.
5. Zaklandvoi, G. A. and Ratanova. V. F. 1987. Stored Grain Pests and their control. Oxonian Press Pvt. Ltd., London.

Open Source Material: This document contains pics along text and pics guide for rapid identification of storage insect pests helpful for understanding the contents of this course

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Stored Product Pests and their Management ENT-508

Topic 1. Introduction

Storage insect pests can be classified as internal feeders and external feeders. Internal feeders can feed on sound grains and their immature stages develop within individual grains. Within a commodity infested by internal feeders, only adults' stages while their larvae are not visible to eyes as these are usually developing within individual grains for example rice weevil, pulse beetles etc. On the other hand external feeders cannot feed on sound grains and they depend on broken kernels for survival inside stored cereal grains. They can feed on flour like material. They have weaker mouth parts for example red flour beetles, saw toothed grain beetle etc.

Internal feeders	Rice weevil, maize weevil, granary weevil Pulse beetles/cow pea weevil Angoumois grain moth Lesser grain borer
External feeders	Red flour beetle Khapra beetles Lesser grain borer Psocids

Apart from this in stored grains there are some accidentals which do not feed on grains but they come by chance.

Stored Product and Fabric Pests

There are five broad categories of stored product pests. These are based on how these pests feed on grain or other stored products. These categories are internal feeders, external feeders, scavengers, secondary pests, and miscellaneous pests.

Internal Feeders

Internal feeders develop as the larvae feed within kernels of whole grain or seeds such as beans and peas. They feed primarily on whole grain as opposed to processed grain. The main symptom of infestation of these pests is exit holes of emerging adults. Examples include rice and granary weevils, lesser grain beetles, and Angonois grain moth.

External Feeders

These arthropods feed on whole grain and may feed on grain products. Normally, they attack only part of grain such as the germ or softer parts of grain. Examples include the cigarette beetle, cadelle beetle, drugstore beetle, warehouse beetle, Indian meal moth, and Mediterranean flour moth.

Scavengers

These pests only attack grain and seeds that has been processed or injured by other insects. They consume flour and grain parts. Examples include the red legged ham beetle, merchant grain beetle, flour beetle, sawtoothed grain beetle, cadelle beetle, and dried fruit beetles.

Secondary Pests

These pests are found feeding in grain products that are moldy or severely damaged. Such items are frequently found in grain bins, abandoned rodent nests or grain waste found in exteriors or voids in granaries and mills.

Miscellaneous Pests

These types of pests are not as commonly found in grain products. Occasionally, they are found feeding on grain and grain products.

External feeders

Topic 2. Red flour beetle (*Tribolium castaneum*) and Confused flour beetle (*Triboleum confusum*)

Identification. The most commonly encountered flour beetles are the red flour beetle and confused flour beetle. Both are similar in physical appearance. They are flat and oval in shape and usually are 1/8 inches long. Adults are reddish, shiny, and smooth textured. The chief characteristic that can be used to distinguish the adults of each species is the shape of the antennae. The antenna of the red four beetle terminates in a distinct 3 segmented club, while those of the confused flour beetle ends in a 4 segmented club. On the underside of the head, the compound eyes of the red flour beetle are more narrowly spaced than those of the confused flour beetle.



Image red flour beetle. Image by Peggy Greb (Public Domain).

The eggs, larvae, and pupae of both of these species resemble each other closely and are very difficult to distinguish from each other. The eggs are tiny, barely visible to the naked eye and typically tend to be a white color or at times even colorless. Certain food particles (e.g. flour) tend to stick to their exoskeleton. The larvae have 6 legs. The pupae are usually a white or brownish color.

The biology of both species is quite similar. Prior to becoming stored products pests, it is thought that these beetles originally lived under bark and in rotting logs. The life cycle (egg to adult) can range from 1 to 3 years or more depending on temperature. The larval stage development ranges anywhere from 20 to over 100 days; development of pupal stage takes around 8 days. These beetles usually breed in damaged grain, grain dust, high-moisture wheat kernels and flour. When found in flour in large numbers, they may cause it to turn grey and mold more quickly. In addition,

their presence may produce a disagreeable odor due to secretions from their scent glands. They are quite active and will quickly seek cover when disturbed. Due to their small size, these beetles can invade many types of packaging. They are unable to climb smooth surfaces such as polyethylene, plastic or glass. As a result, their dead bodies or living beetles can frequently be found at the bottom of packages made of these types of material.

The females deposit between 300 and 400 eggs. These beetles mainly infest various grains or grain products including, but not limited to cereal, corn meal, oats, rice, flour, and crackers. They are the most common stored product pest in flour mills. Their relative small size permits them to move through cracks and crevices and infest homes and other structures. Once they are in areas with potential food sources, long term infestations can result in a sharp odor or moldy flavor. The red flour beetle is capable of short distances flights; the confused flour beetle is unable to fly.

Topic 3. Saw-toothed Grain Beetle (*Oryzaephilus surinamensis*), Merchant Grain Beetle (*Oryzaephilus mercantor*)



Saw-toothed grain beetle

The saw-toothed grain beetles and merchant grain beetles are closely related, and both are commonly found in kitchen cabinets and other similar locations. Both are very similar in appearance; they are flattened, reddish-brown and about 1/10 inch long. They have 6 saw-tooth-like projections on each side of the prothorax. The merchant grain beetle has a spike-like projection behind the eye; this area is more rounded in saw-toothed grain beetles.

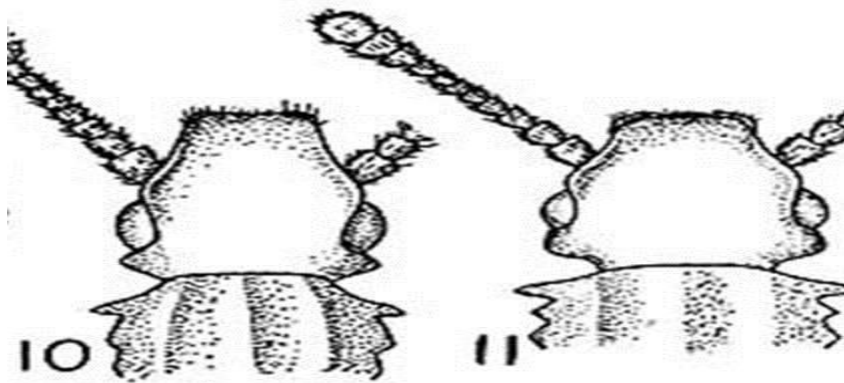


Image. Merchant grain beetle with spiny area behind the posterior margin of the eye (10) and saw-toothed grain beetle with rounded projection behind eye.

Both species are common stored-food product pests that infest materials such as cereal, flour, dried fruit, crackers, candy, dried meats, chocolate, bread, drugs, popcorn, macaroni, cornmeal, corn starch rice, breakfast foods, rolled oats, bran, sugar, bread, dried dog food, raisins, and other foodstuff. They are capable of chewing into food containers made of paper, plastic, tinfoil, cardboard, and cellophane. Once inside, their populations build up rapidly and frequently quickly spread to other food items. They contaminate more food than they consume and characteristically leave infested material to pupate in close crack and crevices. Both adults and larvae are external feeders and commonly consume small food particles, but not whole grains. Sawtoothed grain beetles are quite commonly pests in factories that use chocolate.

Both species deposit their eggs in either small batches or singly. The sawtoothed grain beetles cannot fly, while merchant grain beetles readily can. Adults of both species are somewhat unusual for stored product beetles, in that the adults generally live about 6 to 10 months; a few can survive as long as 3 years or more. Female sawtoothed grain beetles typically emerge in the spring and deposit up to 300 eggs. Egg deposition typically occurs a week after adult emergence and can

last up to nearly a month. Their life cycle is quite rapid and can be completed in less than a month under ideal temperatures. The merchant grain beetles deposit around 200 eggs in an average of 35 days, and require a little more than a month to complete their life cycles. These beetles may produce several generations a year at high temperatures and moderate relative humidity, 85°F to 95°F and 70% RH. At lower temperature, this number is greatly reduced. The sawtoothed grain beetle prefers cereal-based products, whereas the merchant grain beetle is attracted to dried fruit seeds and nuts.

Topic 4. Khphra Beetles (*Trogoderma granarium*)

Worldwide, this is one of the top pests of seed, grain and grain products. It is considered as one of the world's 100 worst invasive species. Infestations are difficult to eliminate due this insect's ability to survive without food for long periods, its preference for dry conditions and low-moisture food, and resistance to many insecticides. There is a federal quarantine that restrict the importation of rice into the U.S. from countries with known infestations of this beetle. Populations can build quickly in a short time under hot, dry conditions. Grain damage, depending on existing conditions, often reach 30 to 70 % . Feeding and contamination by these beetles results in weight loss, reduction in grade, and quality to processed products.

As with many beetles in this family, the larval body has barbed hairs that can contaminate grain. Exposure to grain contaminated with these hairs can lead to dermal and gastric health hazards. The hairs can cause skin irritation in individuals handling heavily infested grain. If swallowed, victims can experience ulcerative colitis. This is particularly distressing for young children who develop vomiting and diarrhea and refuse food.

Adult beetles are brownish and 1.6 to 3 mm in length. Total larval body length is .25 to 3 mm, a little more than half of which terminates in a long tail of hairs. The color is uniformly yellowish-white, except for the head and body hairs which are brown.



Left image Adult Khaphra beetle. Right image larvae Khaphra.

Khaphra beetle prefers grain and cereal products, particularly wheat, barley, oats, rye, maize, rice, flour, malt, and noodles. This pest will feed on almost any dried plant or animal matter, including dog food, dried orange pulp, bread, and dried coconuts. Khaphra beetle can feed on products with as little as 2% moisture content and can develop on animal matter such as dead mice, dried blood, and dried insects. Reported grocery store commodities include bread, dried coconuts, cornmeal, crackers, white and whole wheat flour, hominy grits, baby cereals, pearl barley, and wheat germ.

In the absence of food and other adverse conditions such as extremes of temperature, humidity and crowding, larvae of this beetle enter diapause. In this condition, larvae may survive about 9 months. With food, they may live for 6 years. In this state of very low metabolic activity, they are extremely resistant to the effect of contact insecticides or fumigants and complete control of an infestation may thus be difficult.

Adult females die soon after completing oviposition. Adults are usually short-lived; but they have been known to survive several months or years at temperatures below 16 F. Under optimal conditions, Khaphra beetles can sustain a population increase of 12.5 times per year. As a result, populations can build up rapidly in a short time under hot, dry conditions. They can survive in colder climates, heated situations such as warehouses, food plants, and grain storage. Completion of the life cycle usually lasts 4 to 6 weeks, but can last up to 3 years, depending on temperature, available food supply, and potential for diapause. There are usually 4 to 5 generations per year, but there can be as many as 12 under optimum conditions.

Fumigation with methyl Bromide is the most effective treatment.

Topic 5. Drugstore Beetle (*Stegobium paniceum*), Cigarette Beetle (*Lasioderma serricorne*)



Left image. Adult of drugstore beetle.

Right image: adult cigarette beetle.

Both of these closely related species are similar in size (1/8 inch) and shape (cylindrical). In addition, their heads are withdrawn into the thorax and are only slightly visible from a dorsal angle. The drugstore beetle differs from the cigarette beetle in that the former has row of pits running the length of the elytra. In addition, the antennae of the drugstore beetle terminates in 3 elongated segments, while those of the cigarette beetle are saw-like or serrate in appearance. The larvae of both species are white, C-shaped and have 3 pair of thoracic legs.

Feeding Habits. Both of these beetles, as with most stored product pests, are worldwide in distribution. They feed on a wide variety of material including many things that are not consumed by humans. Common foods include flour, meal, breakfast foods, dried dog food, spices (e.g. red pepper, dried tomatoes), rice, raisins, dates, ginger, dried fish, drugs, rodent baits and much, much more. Both species may be serious pests of manuscripts and books. These beetles have been known to bore straight through all pages of a shelved book. They are external feeders and do not typically feed internally in grain. These beetles occasionally feed on wool, hair, leather, and museum specimens. They have symbiotic yeasts that produce B vitamin. This allows them to survive when feeding on material of low nutritional value. The cigarette beetle is a key pest on tobacco feeding not only on stored cigars but also bailed tobacco leaves.

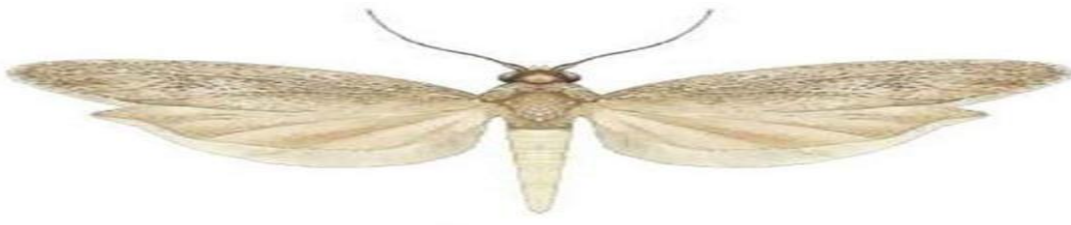
Biology. Both species are attracted to lights during the night or dark cloudy days. Females are capable of producing up to 75 eggs during a 13 to 65 day period. Larval development ranges from 4 to 20 weeks, depending on temperature. Pupation typically occurs off the host and can range from 12 to 18 days. At room temperature, the entire life cycle lasts approximately 2 months, but

can extend as long as 7 at lower temperatures. Several overlapping generations may occur in warm climates or conditions. In colder areas, there is normally 1 generation per year.

Control. Insect traps are available for *L. serricorne*; these contain specific pheromones to attract male beetles, and help to detect and monitor infestations. Infested bulk tobacco in the form of bales or hogsheads can be fumigated using methyl bromide or aluminum phosphide.

With phosphine dosage, rates are 1 gram of phosphine (equivalent to a 3 gram table) per cubic meter - for 5 days at 12 to 15°C and 4 days at 16 to 20 °C and 3 days above 20°C. For localized infestations the approach is to find the infested product, dispose of it, and treat around the area with a residual insecticide such as cypermethrin to kill off any remaining beetles. These beetles are susceptible to cold temperatures which may be used in control or prevention of infestations.

Topic 6. Rice Moth (*Corcyra cephalonica*)



Adult Rice Moth

Identification. The rice moth is similar in size to the Indian meal moth but is much less common. The larvae are general feeders and prefer warm climates. The adult moth has pale buff-brown uniform colored forewings with a 5 to 25 mm wingspan and nearly transparent hindwings. The wing tips are rounded and tightly folded to the body when at rest. The larvae are dull white with long fine hair and dark brown heads.

Biology. As the larvae feed, they web debris, grains, and other small items into galleries or clumps in which they ultimately develop. When fully-grown, they form white cocoons to pupate. Pupae are typically located in food or between pallets and sacks and require 4 to 8 weeks prior to adult emergence. As with many moths, they do not feed and consequently live for 1 to 2 weeks. Females deposit from 100 to 200 eggs on or near potential food sources. This species can have several generations in tropical countries, but in temperate areas they typically annually produce 1. This is

one of the key pests of biscuits, cocoa, sorghum, rice, pearl millet, sorghum, and seeds. Larvae also contaminate foods by the silk that web together food particles, dusts and frass.

Indian Meal Moth (*Plodia interpunctella*)



Adult Indian meal Moth and Larvae.

Identification. Adult moths are approximately 3/8 inch long and have a wing spread of about 1/2 to 3/4 inches. When at rest and viewed from a dorsal angle with the wings folded over the back, the outer half of the front wing is reddish- bronze while the inner half is light gray to tan. The head and thorax are reddish-brown and the hind wings are grayish. Last instar larvae are about 2/3 inch in length and dirty white and sometimes tinged green or pink. These larvae molt 4 to 7 times prior pupating.

Life Cycle. This species is considered the most damaging of the grain-infesting moths. A considerable portion of their damage is the result of larvae spinning silken threads as they move and feed in infested material; as a result, they web food particles together. Besides infesting all whole grains and cereal, they also feed on a wide variety of food products such as dog and cat food, fish food, powdered milk, cornmeal, flour, raisins, dried fruits, nuts, prunes, candies, chocolate, health food, seeds, bird seed, graham crackers, dried red pastas, peppers, and much more.

Biology. These moths fly mostly at night and are attracted to lights. Occasionally, they crawl up walls and suspend from the ceiling attached to a single silken thread. Other times, a few larvae

may be found in a food package along with unsightly webbing, cast skins and frass. Packages of whole wheat, graham flour and corn meal are often infested. Most activity occurs in the warmer months (faster life cycle), but often appear at other times. Some adult moths fly into structures during summer months, but most "hitchhike" inside in packaged goods and groceries. Infestation of this species occurs not only homes, but restaurants, grocery stores, warehouses, pet stores, seed companies, mills, and many more locations where their food is present.

Females deposit between 60 and 300 eggs, singly or in clusters, on or near potential food. Eggs hatch quickly (2 to 14 days). Larvae seek food and ultimately produce a tunnel-like case consisting of frass and silk. As indicated, food becomes matted with silken webbing. In stored grains, the larvae are surface feeders. Once fully developed, larvae abandon their silken tubes and frequently wander a considerable distances from their food source prior to locating a pupation site (often in cracks and crevices). It is not uncommon for some to crawl up walls and pupate where the wall and ceiling meet.

The length of the entire life cycle (egg to adult) may range from as little as 4 weeks and up to 300 days, depending on prevailing temperatures. In cold climates the larvae overwinter, with pupation subsequently occurring in March and adults emerging a few weeks later. There may be up to 5 generations a year, again depending on prevailing temperatures.

Internal Feeders

Topic 7. Angoumois Grain Moth (*Sitotroga cerealella*)

This pest readily attacks corn in both the field and storage. It is quite intolerant to cold temperatures and is not common in the northern United States. The forewings of this small moth (wingspan of ½ inch) are yellow without markings, and the hindwings are grayish in color. The rear edges of both wings are fringed. As with many moths, adults do not feed. Full-grown larvae are usually yellow to white in color, with a yellowish brown head bearing short hair-like projections. Larval size may vary depending on sex, instar, availability of food and environmental conditions. The last larval instar is about 1/4 inch in length.



Angoumois grain moth.

Eighty to 200 eggs are deposited externally on kernels in grooves or holes that are made by other insects. Hatching larvae bore into the seed. The larvae and subsequent pupae remain inside the kernel until adult emergence. The number of eggs produced is dependent on availability of food, season, and temperature. Two or 3 larvae may develop on 1 kernel of corn but with smaller grain, only 1 adult can be produced. There are 3 larval instars, with the last larval instar spinning a silken cocoon within the feeding cavity.

Adults emerge via small round holes in kernels. Upon adult emergence, females release a sex pheromone to attract males of the same species. As with all insects, development from egg to adult varies with temperature. Development is 30 days at 30°C (86°F) and 40 days at 25°C (77°F). As with most moths, the peak time for activity is dusk. Air moving through mold infested grain is quite attractive to these moths.

The Angoumois grain moth can coexist with sawtoothed grain beetles, but the presence of lesser grain borers or maize weevils totally suppress populations of this pest. The larva may become inactive for 4 to 5 months during colder winter climates. This species typically produces 4 to 5 generations per year, although in ideal conditions (heated warehouses), there may be as many as 10 to 12.

Angoumois grain moths can be found infesting a variety of grain and food materials. They attack all cereal grains but are most often found in corn and wheat. It prefers damp grain as opposed to old dry grain and is the only stored product pest that will attack standing grains in the field. In dry stored grain, *Sitotroga cerealella* infestations may cause the grain to heat and increase the overall

moisture content. This encourages mold growth and creates an environment favorable for other insect infestations.

Topic 8. Grain Weevils (*Sitophilus* sp.)

There are 3 species of weevils that commonly infest whole grain, namely the granary weevil (*Sitophilus granarius*), the rice weevil (*Sitophilus oryzae*) and the maize weevil (*Sitophilus zeamais*). All species are very similar in appearance with a few minor but significant differences. These species have chewing mouthparts that are located at the end of their snouts and are about 1/8 to 3/16 inches in length. In the case of developing on small grains such as millet or milo, these weevils are small but are larger when feeding in corn. Unlike the other 2, deep round punctures and light spots are lacking on the granary weevil. Also, the granary weevil cannot fly, whereas the maize and rice weevil can. The larvae of these weevils are legless, humpbacked and white to creamy in color with a small, tan head. The pupal stages of both have snouts, as do the adults. The maize weevil is similar to the rice weevil but larger.



Image adult rice weevil. Courtesy Olaf Lellinger. CC BY-SA 2.5

Rice and granary weevils are not selective and can be found living in and eating not only rice but also wheat, corn, oats, rye, birdseed, beans, barley, sunflower seeds, cashew nuts, cereals, fruits, and even clothing. They are cosmopolitan in distribution having been shipped all over the world in infested grain. The maize weevil has a similar distribution and occurs throughout warm, humid regions around the world, especially in locations where maize is grown.

The egg, larva, and pupa stages of these weevils are found in the grain kernels and are rarely seen. The female eats a hole in a kernel of grain large enough to insert its ovipositor and subsequently deposits a single egg. Oviposition takes as little as 3 minutes and is followed by the female sealing

the hole. Eggs hatch in 3 days at lower temperature (65 degree F.). Feeding occurs within the grain kernel and adults cut exit holes to emerge. Emergence holes of the granary weevil are larger than those of the rice weevil, and tend to be more ragged than those of the granary weevils.

Control/Precautions

Non-Chemical Control. The most effective control measure is to find the source of infestation and eliminate it as fast as possible. A flashlight can be used to examine food products and food storage areas. Infested items should be wrapped in heavy plastic bags, placed in sealed containers for removal, or buried deep in the soil. If an infestation is detected quickly, disposal alone may solve the problem.

Due the rapid reproductive capacity of these weevils, grains stored for a month in the summer or under otherwise warm conditions may lead to infestations. When feasible, grain should be purchased in small quantities and used quickly. In addition, it should be stored in insect-proof glass, heavy plastic or metal containers with screw top airtight lids. When longer storage is required, refrigeration is suggested.

Turnover is especially important when purchasing whole grains from processing plants, grain storage facilities and stores. Fortunately, all stages of these weevils can be killed easily by super heating or cooling. Storage area should be well-ventilated to discourage the presence of moisture-loving stored product pests.

Topic 9. Lesser Grain Borer (*Rhizopertha domonica*)

It can be internal as well as external feeder of stored grains. Adults beetles are very small (approximately 1/8 inches) and dark brown to black in color. The body is cylindrical in shape with the head not visible from a dorsal angle. The prothorax has dorsal blunt knobs or spines. There are distinct rows of pits running longitudinal along the elytra. The antennae are composed of 10 segments, including a 3 segment club. The larvae are white with a stout C-shaped body.



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Lesser grain borer. Image courtesy USDA/Bugwood

This beetle is both internal and external feeder and a serious pest of both cereal products and whole kernel grain. Both larvae and adults readily bore into undamaged kernels of grain and subsequently reduce them into hollow husks. They are also able to reproduce in accumulated "flour" produced as the seeds are chewed up. This beetle is primarily a pest of stored corn and wheat, but it can infest nuts, tobacco, beans, bird seed, cassava biscuits, dried fruit, cocoa beans, spices, peanuts, rodenticide baits, and dried meat and fish.

Adult females lay eggs singly or in groups of up to 30. The eggs are deposited on the outside of the grain or in the fine powdered grain associated with infestations of this beetle. A female can produce from 200 to 500 white eggs during a lifetime. Development from egg to adult depends on temperature. In hot summer conditions, it may take as few as 30 days, but the average is about 58 days. Pupation takes place inside the hollow shell of the seed or in the flour that accumulates in infested grain.

Control/Precautions

Stores, warehouses, feed and health food stores and grocery stores should be monitored for beetle infestations with pheromone traps. Whole grains such as popcorn, wheat berries, bird seed, spice, dried beans, and seeds for sprouting should be stored in insect-proof glass, plastic, or metal, or containers. Infested products should be discarded. There is an unpleasant odor common to with infestations of this beetle; this makes certain foodstuff unpalatable. As with many stored product

pests, sanitation is very important in control and prevention. As a result, shelves and other storage areas should be vacuumed and wiped down with warm soapy water. Small isolated infestations may be controlled with residual and space sprays. However, larger infestations typically require fumigation to eliminate pest populations. Grain protectants are commonly used to hinder infestations, but some are less effective against this beetle than they are against other insects.

Topic 10. Cowpea Weevil (*Callosobruchus maculatus*), Broad Bean Weevil (*Bruchus rufimanus*), Bean Weevil (*Acanthocelides obtectus*).

The adults are relatively small beetles, 0.13 to 0.2 inch in length, somewhat teardrop or triangular in shape, and olive-brown with darker brown and gray patches on the elytra. The elytra are shorter than the abdomen thus leaving a few segments exposed. The larvae are white grubs with a brown head. They are about 1/8 inch long at maturity and have a wrinkled, hump-backed appearance. Depending on the species, the eggs of these beetles are typically glued to a pod or bean (cowpea weevil), to green pods (broad bean weevil), or deposited loosely among beans or cracks in the pods (bean weevil). The larval and pupal stages remain inside the bean. The cowpea weevil is possibly the most common of these beetles in California. Infestations may originate in the field via adults moving to bean fields from trash beans in planters, used sacks, harvesters, or feed areas. The cowpea weevil commonly attacks dried beans and as a result, can be a serious storage pest. As with cow pea weevils, bean weevil infestations can originate in the field and from trash beans. The bean weevil will readily consume dried beans and is frequently a pest in stored beans. Broad bean weevil infestations occur in the field, but this pest is not a storage problem.



Image. Beans infested by bean weevil.

Depending on prevailing temperatures, eggs hatch in 3 to 30 days; the emerging larvae bore into the seeds where they feed until mature. Pupation occurs in the seed which is followed by the adults cutting round holes through the seed coats. Multiple generations will occur as long as food is available and viable temperatures prevail. Infestations of these weevils in the field are frequently not obvious. Heating or freezing temperatures can be used to control these weevils. Control may be achieved by exposing peas or beans to 0 degrees F or less for 4 days. The beans may be stored at freezing temperature to prevent reinfestation, or they may be stored in containers. In order to avoid possible development of mold, the beans should be thoroughly dried prior to storage

Miscellaneous Stored Product Pests

Topic11. Grain Mites/Flour Mite (*Acarus siro*)

This is one of the most common and important mites that infest feed products and other food including dried vegetables materials, cheese, cereal, corn and dried fruits. Populations of the grain mite have the capacity to explode under high moisture conditions and are often associated with fungal growth. With extreme infestations, a brownish tinge often covers the commodity. This is called "mite dust." This coloration is actually due to the light brown color of the mite legs. There is a minty odor associated with such a heavy infestation, especially if the mites are crushed. Grain mites are very common and widely distributed in temperate regions of the world. In tropical areas, they are less common unless there is a continuous influx of new mites (via contaminated products)

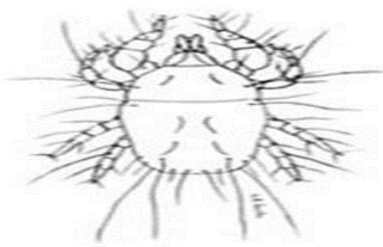


Image: Grain mite

Identification. These mites are pale, pearly or grayish white with legs varying in color from pale yellow to reddish-brown. Each leg has a single claw at the end. As with all mites, they are smooth, wingless, soft-bodied creatures. The males are from 0.013 to 0.017 inches in length and the female

varies from 0.014 to 0.026 inches in length. Diagnostically, the males of this species have enlarged forelegs which bear a thick ventral spine. Immature mites are similar in appearance to the adults, with the exception of the larvae which have 6 legs. Mite eggs are oval, smooth, white, and almost not visible to the naked eye.

Biology. The female is capable of depositing up to 800 eggs at a rate of about 20 to 30 a day. These are either deposited singly or scattered over the food material. The entire life cycle is quite short and may be completed in as little 9 to 11 days, under ideal environmental conditions (90% RH and 75 F). Of course, temperature is the main factor determining the length of development.

Control. Prevention is generally considered the best strategy to prevent problems with this pest in stored grain. Adequate sanitation prior to introduction of new grain will typically decrease the need for the use of pesticides. This typically consists of the removal of old grain and dust in and around grain bins, including from floors, corners, and walls and any that has been spilled on the exterior of a bin.

Subsequent to this and when all needed repairs have been accomplished, various surfaces inside and outside the bin should be treated, including in all cracks, crevices, around doorways and other location where insects and mite can hide. Pesticide application should be applied several weeks prior to introduction of new grain.

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Topic 12. Booklice (Psocoptera)

Identification. Booklice or psocids are typically less than 1/16 inch long and are light yellow, colorless or grey. They have soft bodies with chewing mouthparts and relatively long antennae. The head and abdomen are larger than the thorax. One of the key characteristics of this order is that the clypeus is swollen. This basically means they have a fat lip that projects forward when viewed from a dorsal angle. More simply, they just look like booklice. Some are winged but the forms that are typically found in the food products or cereal are wingless. Once you have seen one, that is pretty much it.



Image: Booklice.

Biology. Many species are parthenogenetic, meaning that can reproduce without mating. Females can produce about 60 eggs during the warm summer months and their life cycle (from egg to adult) can be completed in less than 1 month. When cool temperatures prevail, female booklice produce fewer eggs and the time required to complete their life cycle is over 3 months.

Females lay their eggs singly. These eggs are commonly covered by debris. They exhibit gradual metamorphosis or put more simply, the nymphs look just like adults, except that they are much smaller and not capable of reproducing. Most species normally have 4 nymphal instars. These nuisance pests feed on molds and quickly develop on any food material that has high moisture content, including cereal and cereal products. As a result, they are a nuisance and high levels can render some foods unfit for consumption. They are also called booklice because paste of wallpaper and book bindings can support mold growth. Besides feeding on the mold, the paper of books may be attacked directly by these pests. In these cases, the actual damage is insignificant.

Control. The simplest and easiest means of control is to eliminate moist environmental conditions. Infested food material should be eliminated and susceptible foods should be kept dry. The use a dehumidifier or fan or increasing sunlight in a damp room will typically help eliminate conditions favorable to these nuisance pests. Bring the humidity levels down below 50%.

FABRIC PESTS

Topic 13. Black Carpet Beetle (*Attagenus unicolor*)

This is the most common and most destructive of the 5 species of carpet beetles in the U.S. This black beetle is found throughout North America. It is believed that this pest may have been imported to the United States in the early 19th century from Europe, where it is not considered a major pest. Humidity or the lack of is important in the development of this beetle. In the south, high humidity often results in its eggs becoming moldy, while in the north, lower humidity is typically favorable for a successful egg hatch.



Image: Adult black carpet beetle and larva.

Adults are dark brown or black, oval shaped and 1/8 to 3/16 inch in length. They can live 9 months to 3 years, depending on food availability and other environmental factors. The larvae are elongate, carrot-shaped, golden to chocolate brown and have a tuft of very long, curled, golden-brown hair at the end of the abdomen. This species pupates in its last larval skin. The pupal stage lasts 6 to 24 days.

This species exhibits complete metamorphosis with egg, larva, pupa, and adult stages. This entire cycle can be completed in 2 months to 2 years depending on temperature. Females deposit

approximately 50 white eggs which hatch in 6 to 10 days. Eggs are deposited in cracks, lint, and similar locations but typically near a larval food source. The 5 to 11 instars may require 3 months to nearly 2 years to reach maturity and ultimately reach ½ inch in length. Their hairy caste skins (molted exoskeletons) are often seen on infested material and can readily be mistaken for living larvae. The pupation lasts 6 to 24 days.

This beetle may also be a pest of stored products feeding on grain, nuts and cereals. Infestations of these beetles result in most fabrics becoming useless or at least aesthetically unappealing. In addition, exposure to infestations of these pests may result in allergic reactions to their cast skins, beetle fragments, or dust. These beetles will attack any products containing keratin, a principal protein found in animal hair and feathers. Synthetic fabrics not derived from animal matter may also be attacked. Insect collections are readily attacked by these beetles.

Careful inspection is the initial and possibly most important step in preventing and controlling infestations of this beetle. It is essential to examine all susceptible fabrics from rugs to mounted animal specimens for presence of the various stages of these beetles, damage and cast skins. Keeping in mind that these beetles attack a variety of grains and similar products, these should also be examined. Since adult beetles are primarily pollen feeders, any cut flowers should also be examined for their presence. With ongoing infestations, it might be worthwhile to install screens around windows and make sure outside doors are tightly fitted to avoid adults from entering structures. These beetles are readily attracted to birds and rodent nests. In cold conditions (winter), these beetles readily move indoors. Location and removal of such nests before winter can also minimize infestations.

Vacuuming can be useful in removing various types of debris (animal hair and lint) that serves as a food source for these beetles. Any infested articles should be eliminated. In the case of valuable items, they can be treated by any of several options. Furs can be placed in cold storage at temperatures around 40°C. Also, some items may be frozen for a week in an effort to kill all beetle larvae.

In the case of a heavy infestation, insecticide treatment may be needed. Prior to using insecticides, the area should be thoroughly vacuumed.

Webbing Clothes Moth (*Tineola bisselliella*)

This species is also known as the common clothes moth or simply clothing moth and belongs to the family Tineidae.

Topic 14. Control measures

Prevention of Infestations. The first step in any overall control of stored product pest is prevention. If possible purchase dried food in packages that can be used up in a short time. Although buying such products in bulk may be economical if these remain around for long periods of time there is and increases the chance of eventual infestation. Ideally such products should be used up in 2 to 4 months Keep foods in storage less than two to four months. Obviously older packages should be used before older packages of the same material. Open packages of the same material should be used before closed package

When purchasing packaged foods with clear plastic or wax paper coverings, they should be checked for the presence of insects as these types of material on occasion are sometimes infested prior to introduction into homes or other structures dealing with food. Susceptible food materials should be stored in insect-proof containers, such as heavy plastic, metal containers or screw-top glass. Generally speaking, the lids of metal kitchen canisters are not tight enough to exclude insects of gaining access to their contents. On the other hand, some plastic containers with tight fitting lids may prevent entrance of most of the stored product pests.

Packaging. Insect free products are occasionally infested prior to reaching the consumer. One of primary functions of packaging is to keep stored products free of pests prior to and after reaching market. As previously discussed, these types of materials vary considerably as to their vulnerability to insect penetration and subsequent infestation.

In most cases these pests deposit their eggs on the outside of packaging with hatching subsequently penetrating susceptible packaging. Various species of stored product moth larvae crawl until reaching an opening. Locations near closures are the weak spots with folds and seams possibly providing a first biting point for these larvae. In one report, 75 percent of initial infestation occurred in folds in the corners, overwraps, corners of a carton, or a pinhole. Obviously metal cans

and sealed glass jars with tight fitting lids typically totally exclude insects. Of course there is always the possibility that material could be infested prior to packaging.

Stored Product Pest Control in Grocery and Retail Stores. Grocery stores, supermarkets, and specialty retail stores create unique problems as far as stored product pest control. These are due to the sheer volume of merchandise and tremendous variety of foods shipped in from all over the world. Food often spills behind and under large shelves and gondolas leaving hard to reach reservoirs of food for insect breeding sites. The void created by large back to back shelves or gondolas are especially difficult to reach for cleanup. Tunnels in floors for refrigeration lines create additional voids where food can accumulate. Storage areas in supermarkets are limited and sanitation is often poor. Space treatment does not typically penetrate packages nor reach inaccessible areas where insects are breeding. Such treatment is of limited value without proper cleaning. If space treatments are used, food such fruits and vegetables must be properly covered.

Stored Product Pest Control in Warehouses. As with most type of modern pest control an integrated approach will give best control in this type structure. Key items to consider in warehouse management are exterior entrance management, inspection of incoming products, proper rotation of stored products including the FIFO principle (first in, first out), floor level sanitation, pallet management, and interior and exterior light management.

Pests may enter storage or food processing facilities in two ways, namely penetration through ineffective pest-proofing of walls, doors, windows and roofs, and entry with commodities, ingredients or other raw materials and/or supplies. Windows should be screened and doors to the outside should be tight fitting. Air doors can be used on loading dock to prevent insect entrance. All incoming products should be closely screened for signs of infestation. Cracks, crevices and other places should be filled where pests may hide.

Warehouses have several areas of activity where pests must be controlled. The building exterior and the area around the plant should be kept as clean as possible. Outside the building all exposed dirt surfaces, parking lots and road should be paved and lawns. This will reduce contamination from dirt, microbes and other airborne particles. Good drainage should be established to help keep these areas clean and dry. Many stored product insects evolved in natural setting and therefore are

commonly found outdoors. Of course the same can be said of rodents. Rodent-proofing and bird-proof loading docks, doors, walls, windows and roofs should be present.

Outside lighting should be away from buildings and focused toward buildings. This helps keep night-flying insects away from doors and windows. Potential bird roosting areas should be screened. Equipment should be stored so it does not become a place for pests to hide.

There are a variety of traps and monitoring systems that can detect initial small level infestations of insects and or rodents. It is extremely important to eliminate these prior to where they reach a level where it is difficult to eliminate. Insect pheromone traps should be placed in a 50 foot grid pattern throughout a warehouse with the exception in front of doors. Products should be visually inspected on a regular basis as pheromone traps are not available or not effective for all stored product pests. Where possible, equipment should be located off the floor and away from walls for inspect. The same should be followed for product storage racks

As indicated product rotation is of the essence. The longer a product remains in a warehouse the better the chance it will become infested. Sanitation is of utmost importance. In essence a warehouse is a third party clearing house (between the food manufacturer and retailer). Regardless it is their responsibility to minimize the chance that stored products do not become infested while on their premises.

Chemical Controls. Bait stations should be used for rodents. Bait stations are not only effective means of controlling rodents but maintain grain based in a safe location and virtually eliminate any chances of product contamination. Nonresidual insecticides should be used for space, spot and crack and crevice treatment.

Topic 15. Grain storage principles

a) Conditions of the Grains

It was mentioned that only clean, unbroken kernels should be selected for storage. Now two other elements can be added to this list. The grain should be dry and it should be cool when it is put into storage.

b) Climatic Conditions

Grain stores best in weather which is dry and cool. Unfortunately, the weather is not always dry and cool. During the serious rainy season even well dried grain can become wet again if it is exposed to very wet air or rain. Since grain must be stored during all kinds of weather the type of storage method chosen must protect the grain from the worst possible weather conditions.

c) Store Conditions

A grain store must perform one task: the store must protect the grain from its natural enemies: mould and fungus, insects, rats, birds, and other animals.

To do this a grain store should have the following properties

- The store must be dry.
- The store should be cool.
- The store should keep out the sun.
- The store should be clean.
- The store should have no holes or cracks in the roof, walls, or floor.
- The store might need to be treated with insecticide.

It is good to know why these six conditions should be followed. First, a good grain store should keep the grain cool, dry, and out of the sunlight because cool, dry grain respirates, or breathes, very slowly. The seed coat can resist mould and insect attack if the grain is kept cool and dry. Second' a grain store should be kept clean and in good repair (no holes or cracks in walls, etc.) so that insects and rats cannot enter or hide and live inside. Finally, the last item, some stores have to be treated with an insecticide to remove serious insect infestation. It is often difficult to control insects without using chemicals.

Grain moisture content

It is always advised to store grain ideally with around 9-10 % moisture content of grain. At 9-10 % moisture content most of storage insect pests do not attack. But some insects can attack at very low grain moisture content e.g., khapra beetles. For these kinds of pests attacking stored grains other necessary control measure should be adopted.

Pictorial Guide for Rapid Identification of Common Adult Storage Insects

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ABSTRACT

To assist analysts with identification of the adult insects most commonly found in foods, detailed drawings of 21 such insects are provided. For each example, accompanying text summarizes the identifying characteristics and gives additional information about its name and habits. Larger scale drawings of adult antennae and mandibles are included with most examples.

The purpose of this article is to provide the analyst working in food regulatory and processing areas with a clear, concise set of drawings of 21 of the most commonly found insect pests in stored products. This pictorial reference will enable analysts without extensive training in insect identification to make quick, accurate determinations of the identities of whole adult insects.

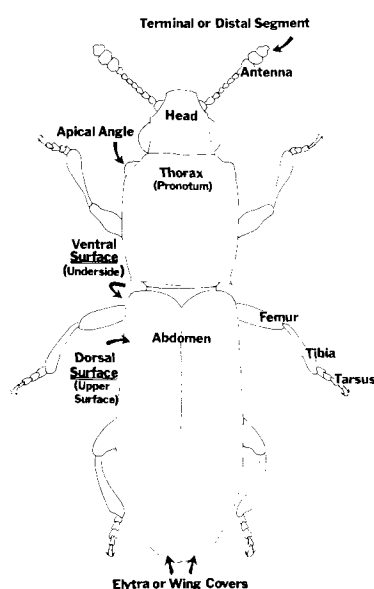


Figure 1. The tarsal formula referred to in the text is a three number formula which represents the number of tarsal segments of the front, middle, and hind legs, respectively. For example, the tarsal formula of 5-5-4, in the tribolium, indicates that the tarsi of the front and middle legs are made up of 5 segments, and the tarsus of the hind leg is composed of 4 segments.

The illustrations accurately portray authentic insects in the Food and Drug collections at the New York Regional Laboratory. The article has been kept as brief and simple as possible, and is based mainly on pictured forms of the most commonly encountered storage insect pests (1-5). Key characteristics are accentuated by diagnostic arrows. Some of the insects have such distinctive forms that they may be identified at a glance, while others may require more detailed study under higher magnification to confirm their identity. Closely related insects which are similar in appearance have been juxtaposed for comparison, and the characteristic differences useful for spot identification noted.

An illustration (Fig. 1) has been included as a pictorial glossary to familiarize the user with some of the morphological terminology. The use of technical terms has been kept to a minimum, and the descriptions simplified as much as possible to aid the non-entomologist in identifying insects encountered during the course of food analyses.

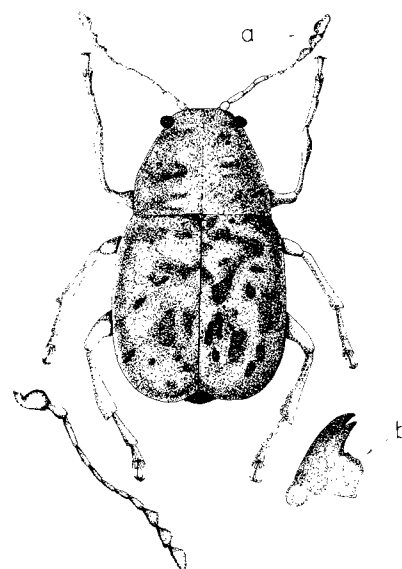


Figure 2. The coffee bean weevil, *Araecerus fasciculatus* (De-Geer), is ca. 3-4 mm long. It is stout, with a mottled appearance, ranging in shade from dark brown to grey, with dark

brown legs and antennae. The head is slightly prolonged into a short, broad snout. The general shape of the insect may cause confusion with the bean and pea weevils (Fig. 3 and 4). The coffee bean weevil, however, may be distinguished by the distinctive enlargement of the 3 terminal antennal segments (a). The mandibles are mostly triangular, with two teeth and a large molar projection (b). The base of the outer margin extends down to form a prominent rounded knot. Coffee bean weevils are found in coffee, cocoa beans, dried fruit, corn, and related products. They are found in many countries, and are especially abundant in the Southern states. Coffee bean weevil is not considered a major grain pest.

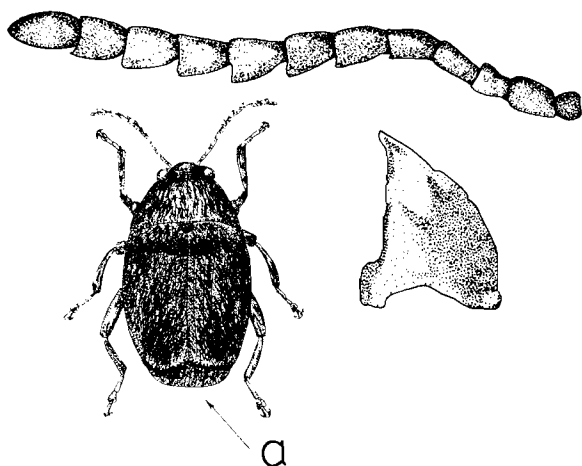


Figure 3. The pea weevil, *Bruchus pisorum*, (Linnaeus) is ca. 4 mm long, generally brown in color with flecks of black, white, and grey, creating a mottled effect. The body is densely covered with hairs above, while the underside is black and shiny. The legs and antennae are mostly black. The body is oblong-oval in shape, with a steep inclination of the exposed terminal abdominal segment, giving a "chopped off" appearance to the posterior end of the beetle (a). The femurs of the hind legs are enlarged and bear a tooth. The 3rd tarsal segment is bilobed, as in Fig. 5. The thorax is more broad than it is long. The eyes are C-shaped (emarginate) around the base of the antennae, which widen gradually toward the end. The mandible is simple, having a slanted triangular appearance. Pea weevils are found inside peas and other legumes. They attack only living seeds in the field, and cannot reproduce in dried stored seed. Only 1 pea weevil will be found in a single seed.

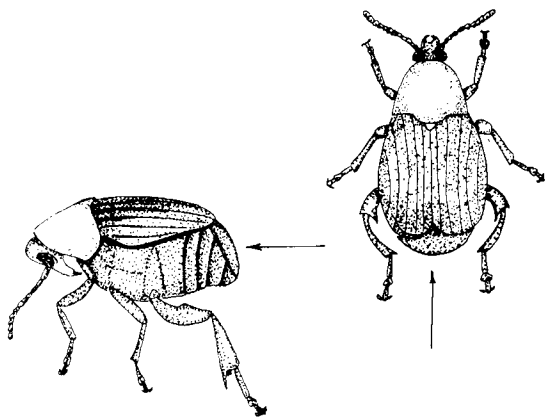


Figure 4. The bean weevil, *Acanthoscelides obtectus* (Say), is nearly identical to the pea weevil in appearance and in general habit, though smaller and less robust. It is about 2/3 as large

as the pea weevil measuring ca. 2.5-3 mm. The antennae widen gradually toward the distal end. There are distinct lines (striae) on the wing covers (elytra). Like pea weevils, bean weevils are encountered in leguminous seeds, though they may attack dried stored seed, as well as that growing in the field. Unlike the pea weevil, several bean weevils may be found in a single seed.

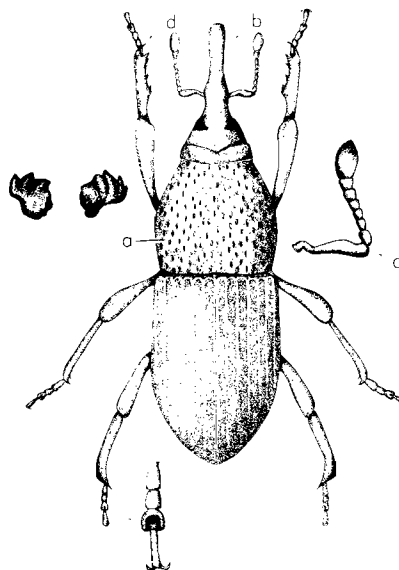


Figure 5. The granary weevil *Sitophilus granarius* (Linnaeus), is ca. 3-4 mm long, and is brown to reddish brown. The prothorax bears punctures, distinctly oval in shape across its surface (a) and there are no wings under the wing covers. Both of these characteristics help distinguish it from the closely related rice weevil. The insects of the *Sitophilus* genus (see also Fig. 6) are easily distinguishable from other beetles by the long snout (rostrum) (b). The antennae are elbowed (geniculate) (c), with the first segment near the head elongated and at a right angle to subsequent segments. The antennae terminate in a distinct club. The end of the tibial segment of each leg bears a distinctive apical hook (d). The third tarsal segment is composed of two lobes (bilobed), as pictured in the inset. The tarsal formula is 5-5-5, though it appears 4-4-4. Mandibles are small and rounded, with triangular teeth, and look somewhat like a chicken's comb. The granary weevil is found throughout the world, but most commonly in temperate climates. It is found in all common grains, including wheat and corn. It is unable to breed in loose or mealy material, such as flour or semolina, but breeds readily in manufactured cereal products, such as macaroni.

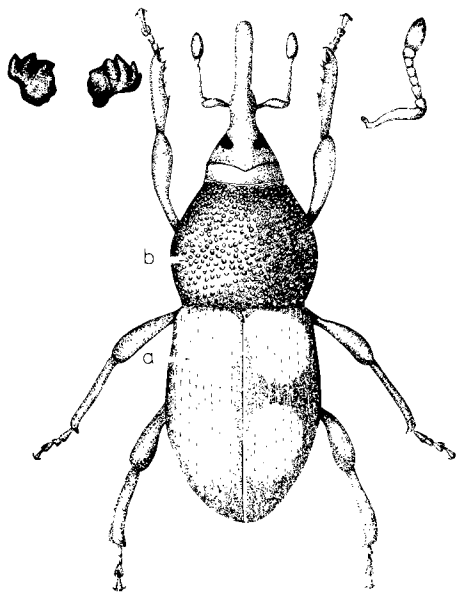


Figure 6. The rice weevil, *Sitophilus oryzae* (Linnaeus), is quite similar in appearance to the granary weevil and close examination is required to distinguish between them. The rice weevil is slightly smaller (2-3 mm). It is also reddish brown to brown, but often with four lighter-colored spots visible on the wing covers (elytra) (a). The punctures on the prothorax are round (b), and fully developed wings are present under the wing covers. The prothorax itself is slightly wider and more rounded than that of the granary weevil. The rice weevil is found in the same variety of products as the granary weevil, and is distributed throughout the world. It is particularly abundant in warm countries.

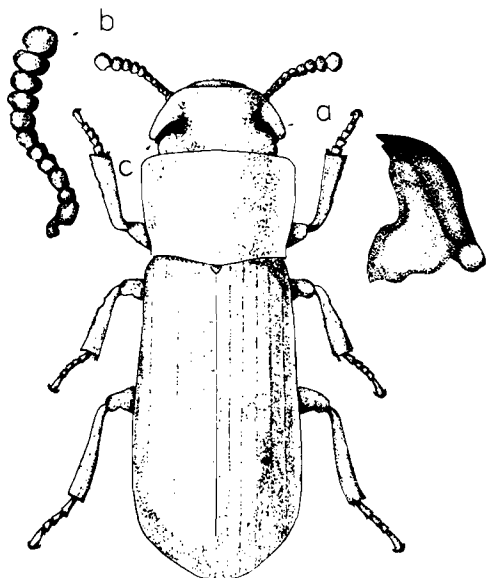


Figure 7. The confused flour beetle, *Tribolium confusion* (Jacquelin duVal) is a ca. 3-4 mm long, with reddish brown color. The head is narrower than the prothorax. The prothorax is distinctly wider toward the head, with sharply rounded corners in front. The rear corners of the prothorax form nearly right angles. Wing covers are ridged lengthwise, giving a striated appearance. Each antenna originates laterally from under an extended frontal area of the head (gena) (a). The gena juts out at a nearly right angle in front of the eye. The antennae widen gradually toward the tip, the terminal segments are being somewhat rounded (about as wide as they are long) (b). The eyes

are "C" shaped (emarginate), extending around the genae. Viewed from above, the width of the eye between the gena and the rear of the head, or the notch separating the dorsal and ventral lobes of the eye, is rather narrow (c). From below, the space between the eyes is nearly three times the width of the ventral portion of the eye. The tarsal formula is 5-5-4. These beetles occur most commonly in flour and milled cereals. They are also found in a wide variety of other food products, such as nuts, cocoa beans, and dried fruits. Infestations occur in granaries, mills, warehouses, and wherever grain or grain products are stored.

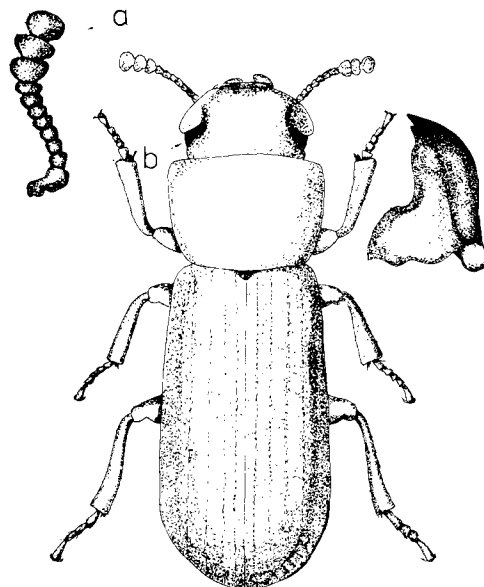


Figure 8. The red flour beetle, *Tribolium castaneum* (Herbst), is 3-4 mm long, reddish brown, and in most ways similar to the confused flour beetle. Close examination is necessary to distinguish between the two species. The antennae of the red flour beetle widen abruptly at the distal ends forming a distinct three segmented club (a). The terminal segment is broader than it is long. The notch separating the dorsal and ventral lobes of the eye is wide and the genae are less prominent than in the confused flour beetle (b). The ventral lobes of the eyes are large, and approximately equal in size to the distance between them. They are found in the same products as the confused flour beetle.

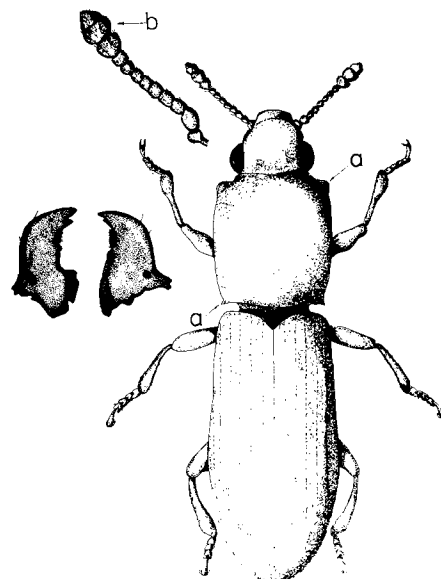


Figure 9. The square-necked grain beetle, *Cathartus quadricollis* (Guerin-Meneville), is an elongate beetle, ca. 3 mm long, reddish brown in color. The prothorax is nearly square when viewed from above. The sides of the prothorax curve out slightly, so that it is widest near the middle. A distinctive projection, almost like a tooth, is formed at each corner (a). The antennae have a three segmented club, with the middle segment being the largest (b). The apical segment is less symmetrical than that of the foreign grain beetle (Fig. 10). The mandibles are not symmetrical. The tarsal formula is 5-5-5, though it appears as 5-5-4. This beetle is found in variety of grains and in cocoa. It is commonly found in stored corn, particularly in the southern states.

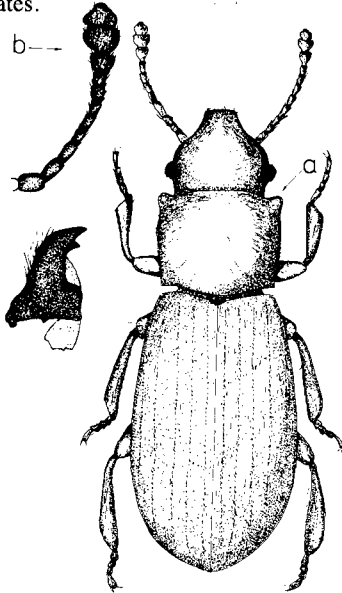


Figure 10. The foreign grain beetle, *Ahasverus advena* (Waltl), is a ca. 2-3 mm long, with a pale brown color. The body somewhat resembles the square-necked grain beetle, but it is smaller and stouter. The prothorax is more broad than long having a single, large, toothlike projection on each front corner (a). The antennae have distinct three segmented clubs (b). As in the square-necked grain beetle, the middle segment of each club is the largest. However, the terminal segments are more symmetrical in this species. The tarsal formula is 5-5-5, although it appears as 5-5-4. It is encountered in various kinds of grains, flour, beans, cocoa, and dried fruits.

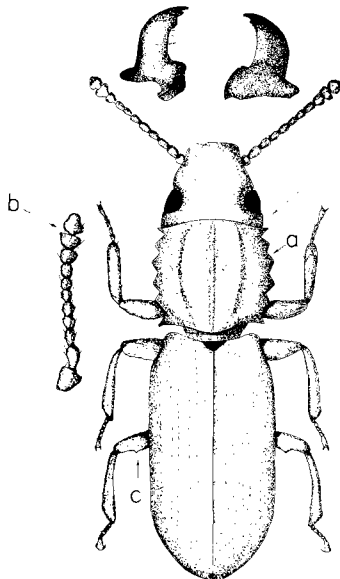


Figure 11. The sawtoothed grain beetle, *Oryzaephilus surinamensis* (Linnaeus), is ca. 2.5-3.5 mm long and colored dark brown. It gets its name from the distinctive serrate or saw-tooth-like margins of the prothorax (a). There are six of these tooth-like projections on each side, and three prominent ridges on the upper surface. The body is slender and flattened. A club is formed by the three terminal antennal segments. The apical or terminal segment is constricted slightly at its base forming a neck as it enters the next segment (b). There is a single tooth-like projection on the femur of the hind leg of the male (c). The tarsal formula is 5-5-5. The sawtoothed grain beetle occurs in a variety of grain products, cereals, dried fruits, nuts, candy, and tobacco. (Also see Fig. 12).

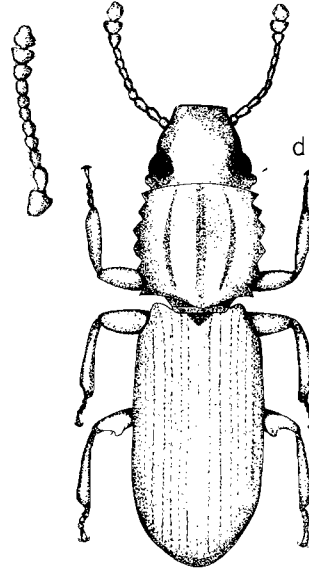


Figure 12. The merchant grain beetle, *Oryzaephilus mercator* (Fauvel), closely resembles the sawtoothed grain beetle (Fig. 11) in size, shape, and color. Close examination of the area of the head behind the eyes is necessary. This area (from the eye to the back of the head) is longer in the sawtoothed grain beetle than in the merchant, where only a short, triangular projection is formed (d). The tarsal formula is 5-5-5. The merchant grain beetle attacks the same products as the sawtoothed grain beetle.

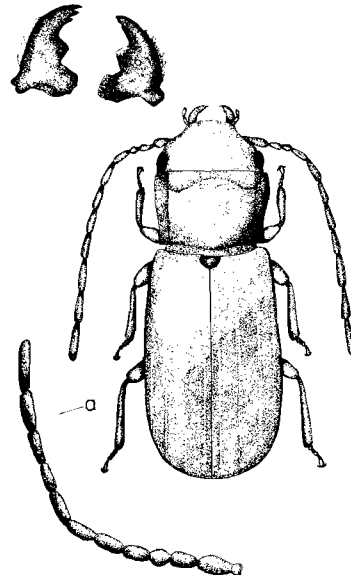


Figure 13. The flat grain beetle, *Cryptolestes pusillus* (Schonherr), and closely related species (*Cryptolestes* sp.) are

small insects ca. 1.5-2 mm long. The color is light brown to reddish brown. The body is elongate and quite flattened, with rather short legs. The tarsal formula is 5-5-5. Antennae are long and thread-like (filiform). In the male flat grain beetle, they are approximately two-thirds as long as the body. In the male of the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), the antennae measure no more than one-half the body length. The last three segments are slightly elongated (a), though there is no distinct club. The prothorax is nearly square, though narrowed slightly toward the abdomen. The wing covers have distinct longitudinal lines running their entire length. The mandibles are sickle-shaped, and have an unusual triangular projection about midway up the inner margin. These beetles are found in cereal grain and flour.

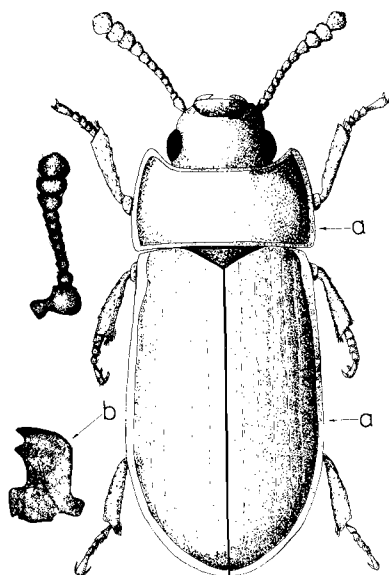


Figure 14. The Siamese grain beetle, *Lophocateres pusillus* (Klug), is ca. 2-3 mm long and reddish brown in color. It is a small flattened beetle, recognizable by the flattened margins of the prothorax and the elytra (a). The prothorax extends forward on either side of the head. Each antenna bears a 3 segmented club. The tarsal formula is 5-5-5. There is a distinctive hump on the lateral margin of the mandible (b). The Siamese grain beetle is usually found in rice and other grain or cereal commodities.

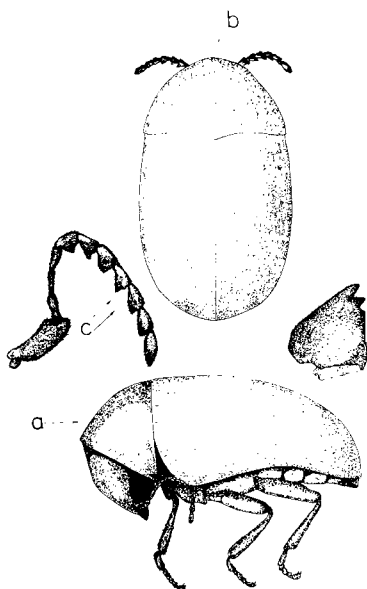


Figure 15. The cigarette beetle, *Lasioderma serricorne* (Fabricius), is ca. 2 mm long, with a light to very light brown color. The adult beetle is oval, with the head and prothorax bent downward, giving the insect a humped, convex appearance (a). The head is curved downward (deflexed), and is almost completely obscured from above (b). The wing covers (elytra) are not striated, and appear rather smooth. The antennae are serrate, with a saw-like appearance (c). The segments are nearly uniform, not forming a club. The tarsal formula is 5-5-5. The adult mandible is somewhat triangular, with two triangular apical teeth, and no molar projection. The cigarette beetle is most commonly found in spices as well as in cereals, seeds, crude drugs, and of course, tobacco.

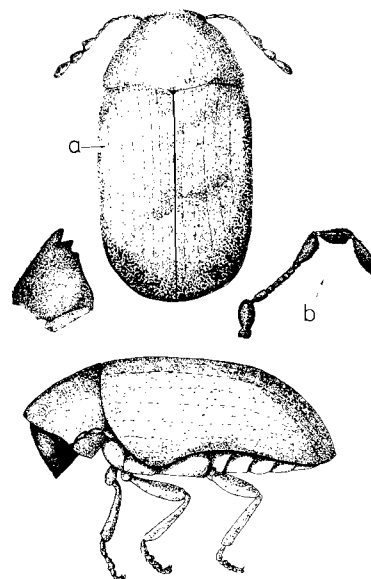


Figure 16. The drugstore beetle, *Stegobium paniceum* (Linnaeus), is ca. 2-3 mm long and brown. It closely resembles the cigarette beetle (Fig. 15), but is slightly larger and more elongate, somewhat darker in color, and densely covered with short hairs. The wing covers are clearly striated (a), and the antennae are enlarged at the tip to form a three segmented club (b). The mandible is indented along the outer margin toward the base. The drugstore beetle attacks a similar variety of products as the cigarette beetle, as well feeding on pharmaceutical drugs.

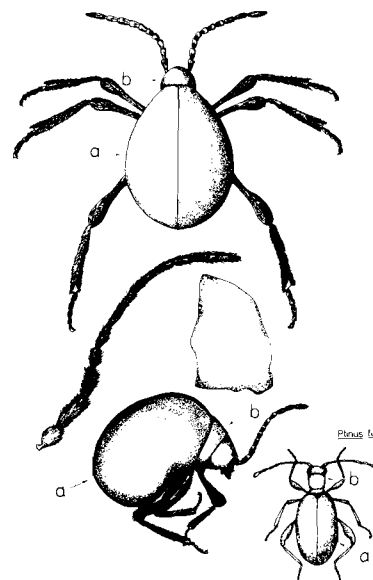


Figure 17. The spider beetles, *Gibbium psylloides* (Czenpinski) and *Ptinus fur* (Linnaeus), are ca. 3-4 mm long, reddish brown to black. They can be recognized by their long legs and spider-like appearance, with a constriction of the prothorax near the base. The body is usually stout and hairy. The antennae are rather long and more or less uniform throughout. There is no club. *Gibbium psylloides* has an almost globular abdomen (a), shortened prothorax (b), and elliptical eyes. The mandible is characterized by a triangular protrusion midway along the inner margin, and a single apical tooth. The tarsal formula is 5-5-5. Spider beetles are associated with stored cereals, vegetable material, and milled flour. They may also be found living on debris of such commodities as cocoa beans, grains, seeds or insect remains.

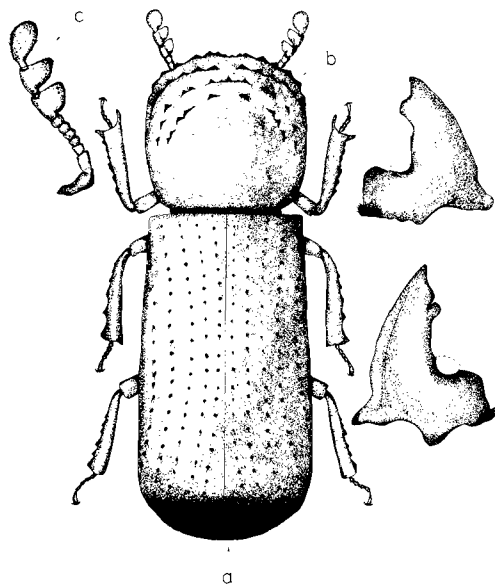
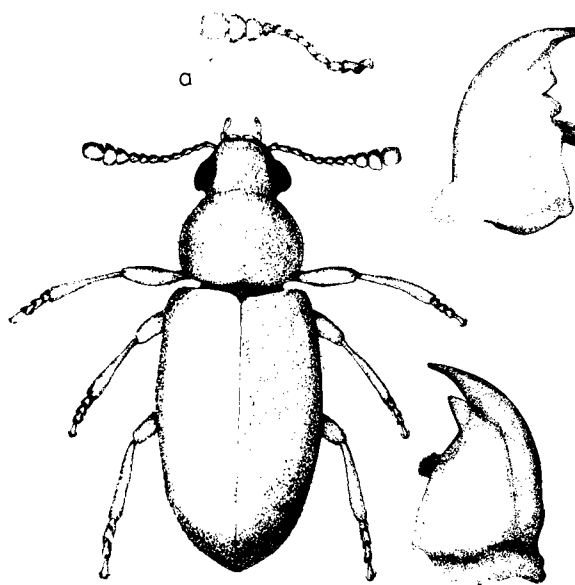


Figure 18. The lesser grain borer, *Rhyzopertha dominica* (Fabricius), is ca. 2-3 mm long and dark reddish brown to nearly black. The body is nearly cylindrical, blunt at the rear (a), and has a well developed hood-like prothorax. The head is bent under the prothorax and directed downward and so concealed from above. The prothorax has rasp-like teeth (b) arranged concentrically, forming a crest along the front. The teeth are smaller toward the sides. The wing covers are covered with pits, arranged in rows to form striations. Antennae terminate in large three segmented clubs (c). The first two segments of the club are somewhat triangular. The terminal segment is more rounded or oval. The mandible has a large molar area and irregular apical teeth on the inner margins. The tarsal formula is 5-5-5. The lesser grain borer is a serious pest of nearly all grains, especially wheat. It can also be encountered in various seeds, dry roots and cork.

Figure 19. The redlegged ham beetle, *Necrobia rufipes* (De-Geer), is ca. 5-6 mm long, with an iridescent or metallic greenish blue color. The antennae and legs are usually red to reddish brown. The prothorax is rounded and convex, without apparent apical angles. The head is as wide as the front of the prothorax. The antennae are long and end in a three segmented club (a). The body is sparsely clothed in erect hairs. The tarsal formula is 5-5-5. The outer margin of the mandible is curved, terminating in a long apical tooth. There is a tuft of bristles on the inner margin. These beetles are destructive to hams, cheeses, and copra (dried coconut flesh). They are sometimes seen in dried fruits or nuts.

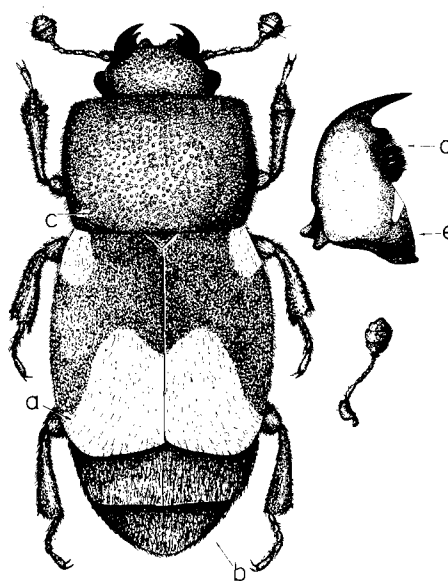


Figure 20. The driedfruit beetle, *Carpophilus hemipterus* (Linnaeus), is ca. 3 mm long. It is brown to very dark brown, usually with a prominent amber brown to yellow spot at the tip of each wing cover (a), and a smaller spot at the base on the outer margin. The appendages are amber or reddish. They are flat, oval insects. The wing covers are short and truncated, leaving ca. one-third of the abdomen exposed (b). The prothorax is broad, curving inward slightly near the head, and prominently punctured with rounded holes (c). The head is

broad, though not as wide as the prothorax, and also bears circular punctures. There are abrupt, somewhat flattened three segmented clubs on the antennae. The terminal segment is roughly strawberry shaped. The tarsal formula is 5-5-5. The mandible bears one long, prominent apical tooth, a large tuft of bristles on the inside margin (d) and a distinct molar projection (e). Driedfruit beetles occur mainly in dried fruits, particularly in those that are slightly fermented.

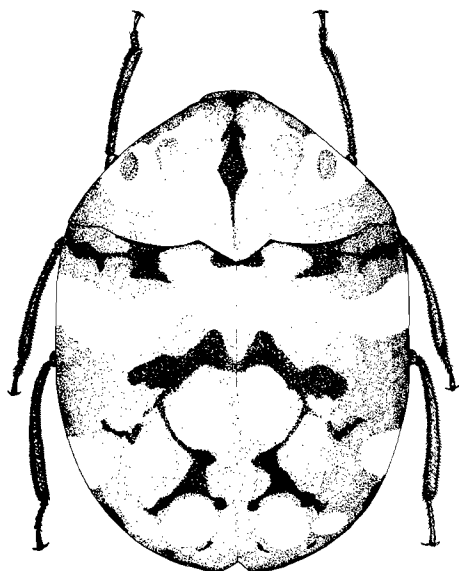


Figure 21. The carpet beetle, *Anthrenus* sp., is ca. 2-4 mm long. The body is covered with short hairs or scales which form patterns of white, black, and yellow. Red is also found in some species. This beetle is a representative of a larger group of dermestid beetles. These beetles are compact and recognizable by their oval or roundly oval, convex bodies. The hairs or scales usually form distinctive colored patterns. The wing covers are convex and cover the entire abdomen. They are not striated. The head is short and directed downward. It is partially retracted into the thorax, and obscured from above. There are grooves in the front of the thorax and the underside of the body into which the antennae and legs may be withdrawn, fitting almost flush with the body surfaces. All the appendages are small. The antennae are clubbed, and usually seen retracted into grooves below and behind the eyes. The tarsal formula is 5-5-5. Carpet beetles attack grains, flour, dried meat, milk, and many other plant and animal products.

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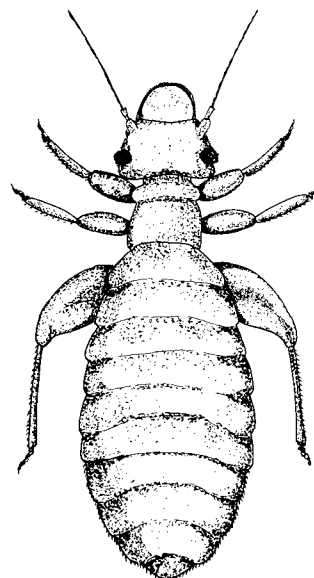


Figure 22. Psocids, *Liposcelis* sp., are small insects, ca. 1-1.5 mm long, colored cream brown to yellowish grey. They are soft bodied, and without wings. The head is large and well developed, broadest toward the body. Eyes are compound and small. There is an enlarged "upper lip", with a hoodlike appearance (a). The antennae are long and many segmented. The femur of the hind leg is quite broad (b). The tarsi are 2 or 3 segmented. Psocids are commonly encountered in products upon with microscopic molds are growing, and they generally feed on this mold. They may also attack cereals or any starchy product. They are often found live in sievings and the debris of such products as coffee beans.

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