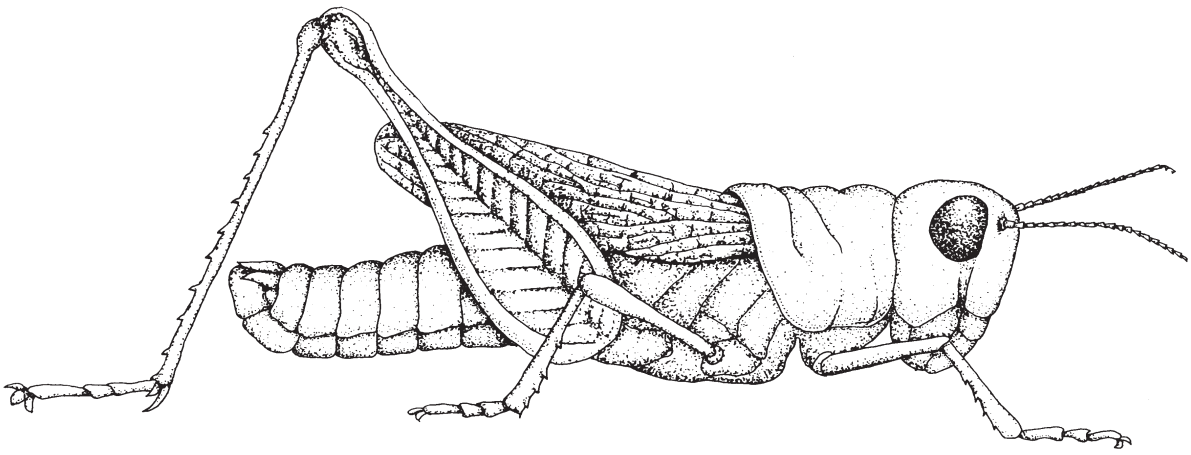

Field Guide to COMMON WESTERN GRASSHOPPERS

Third Edition
Wyoming Agricultural Experiment Station
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Robert E. Pfadt
University of Wyoming

Preface

For some time, grasshopper scouts and supervisors have desired a practical means of identifying common species of grasshoppers in both nymphal and adult stages. The consensus of ideas of APHIS and ARS personnel focused on a field guide that would picture in color not only the adults but also all nymphal instars. In addition the guide should include pictures of diagnostic features of each species. Treatment of 50 species was originally contemplated, but the number increased to 70 as more consideration was given to the species of grasshoppers frequently encountered by scouts working in the 17 western states. Names of 70 species (mainly Acrididae, a few Tettigoniidae) were selected by the technical committee of the Grasshopper Integrated Pest Management Project (USDA 1987-94) and are listed in the project outline of the field guide. From this list the author chose six to twelve species to work on annually. Selection was made on the basis of availability of grasshopper species and of site proximity.

Because new employees often need instruction on grasshopper structure, life history, behavior, and ecology, an introduction covering these subjects was also proposed. The project originally was estimated to be completed in two years but it was soon realized that more time was needed. The first species chosen were common, abundant ones inhabiting sites close to Laramie. As fact sheets on these species were completed, sites farther from Laramie chosen for other common grasshoppers entailed more travel time and left less time for productive work. The paucity of published information on the less researched species and less unpublished data in files of the author required first-hand laboratory and field observations. Another problem encountered was the low densities of certain otherwise common species in recent years, making observation and collection of live specimens more difficult. In spite of these impediments the publication of four new fact sheets in 2002 brings the total number of species treated to 60.

Acknowledgments

The production of this *Field Guide to Common Western Grasshoppers* has required the efforts and expertise of several staff members of the University of Wyoming. I wish to acknowledge their valued contributions that made this publication possible.

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College of Agriculture • The University of Wyoming

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Field Guide to Common Western Grasshoppers

Robert E. Pfadt

Introduction

Nearly 400 species of grasshoppers are known to inhabit the 17 western states. Of these, approximately 70 species are common enough to be encountered regularly by persons scouting for damaging populations. For personnel who lack taxonomic experience, identifying the nymphs and adults of these common grasshoppers is difficult. Yet the need for considering species in control decisions becomes ever more urgent. Control officials need to know both the identities and the densities of species composing infestations to assess accurately the economic threat and select prudent solutions.

There are several reasons why it is necessary to correctly identify species. (1) Species vary in their biotic potential and in their capacity for causing damage. (2) Depending on their food habits, species may be either pests or beneficials. (3) Certain species of pest grasshoppers are highly migratory and often pose a serious threat to distant crops. (4) Species vary in their seasonal cycle (period of hatching, development, and reproduction), which in turn affects the timing of control treatments. (5) Because current chemical and biological methods of controlling grasshoppers are more sophisticated, their effective use requires greater knowledge of the pests' life histories and habits. (6) As environmental impacts of control are more finely evaluated, recognition of pest species of grasshoppers has become essential in the selection of management strategies.

The purpose of this manual is to provide a pictorial guide that will allow plant protection personnel to make grasshopper identifications in the field. Although the surest method for obtaining an accurate identification is submission of the specimen to a specialist, this procedure is not feasible during an expeditious grasshopper survey. To achieve the requisite efficiency in making a useful survey, the scout must be able to identify, and in a short time learn to recognize on sight, the common species inhabiting the infested area.

Grasshoppers are relatively large insects with quite distinct appearances. Diverse traits permit one

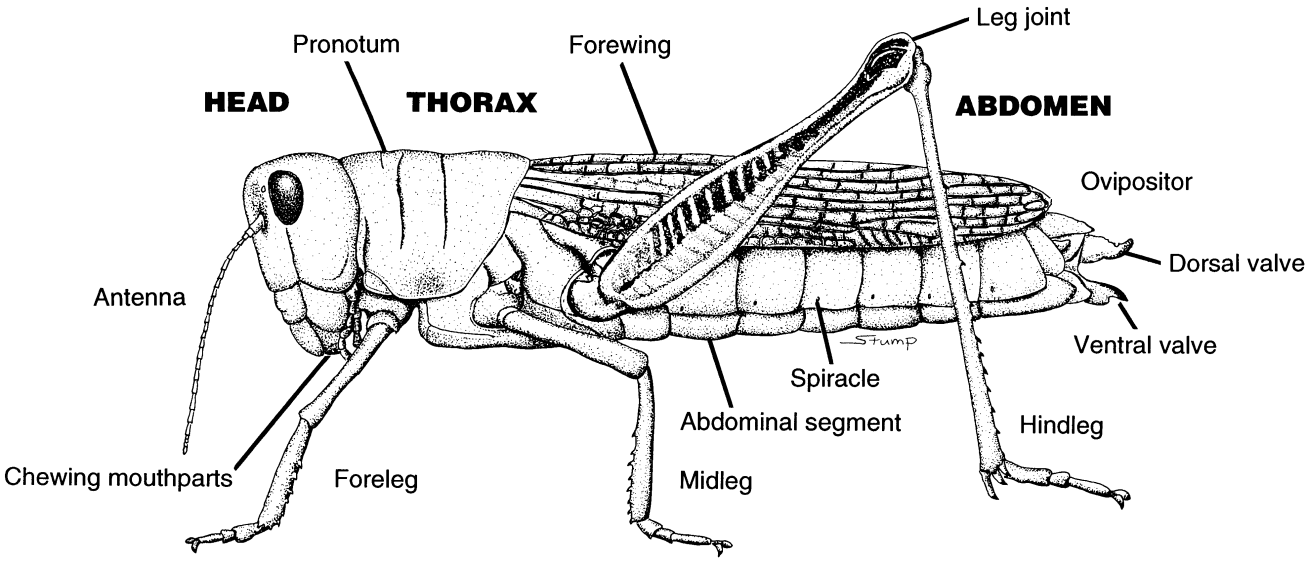

Figure 1. Diagram of a female grasshopper showing characteristic external features. Modeled after *Melanoplus bivittatus* (Say).

to identify a specimen of an unknown species by comparing it with identified museum specimens. One may also identify the specimen by comparing it with good color pictures. When accompanied by illustrations and descriptions of distinguishing characters and their variations, color pictures are probably the best means of accurate identification of an unknown specimen (short of submitting it to a specialist).

This *Field Guide to Common Western Grasshoppers* provides the scout with color pictures of the nymphs, adult male, and female, and illustrations and descriptions of distinguishing characters allowing comparisons with unknown specimens that need identification. The guide also contains distribution maps of species, brief accounts of their seasonal cycles, feeding and reproductive behavior, and habitat preferences. All may serve as additional clues to the identities of specimens as well as provide pertinent information for grasshopper management.

External Anatomy

The basis for classification and identification of grasshoppers consists primarily of the distinctive features of their external anatomy. Gross structures establish the affiliation of grasshoppers with the higher categories of invertebrate animals. For example, grasshoppers belong to the phylum Arthropoda as evidenced by the ringlike segments of their body, their jointed appendages, and their exoskeleton (Fig. 1).

Further segregation places them in the class Insecta, the insects. They have three body regions (the head, thorax, and abdomen) and possess a

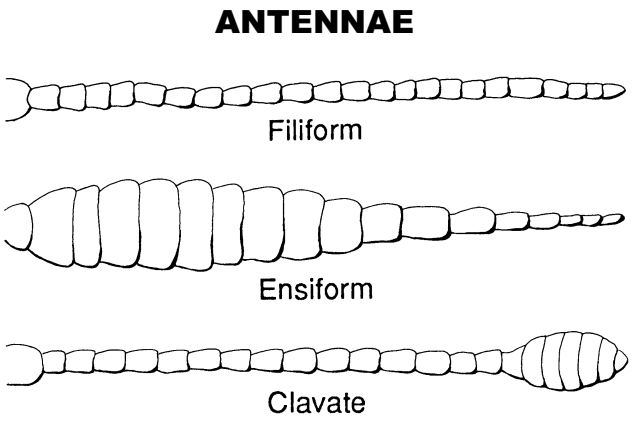

Figure 2. Diagram of three forms of grasshopper antennae: filiform or threadlike, ensiform or sword-shaped, and clavate or club shaped.

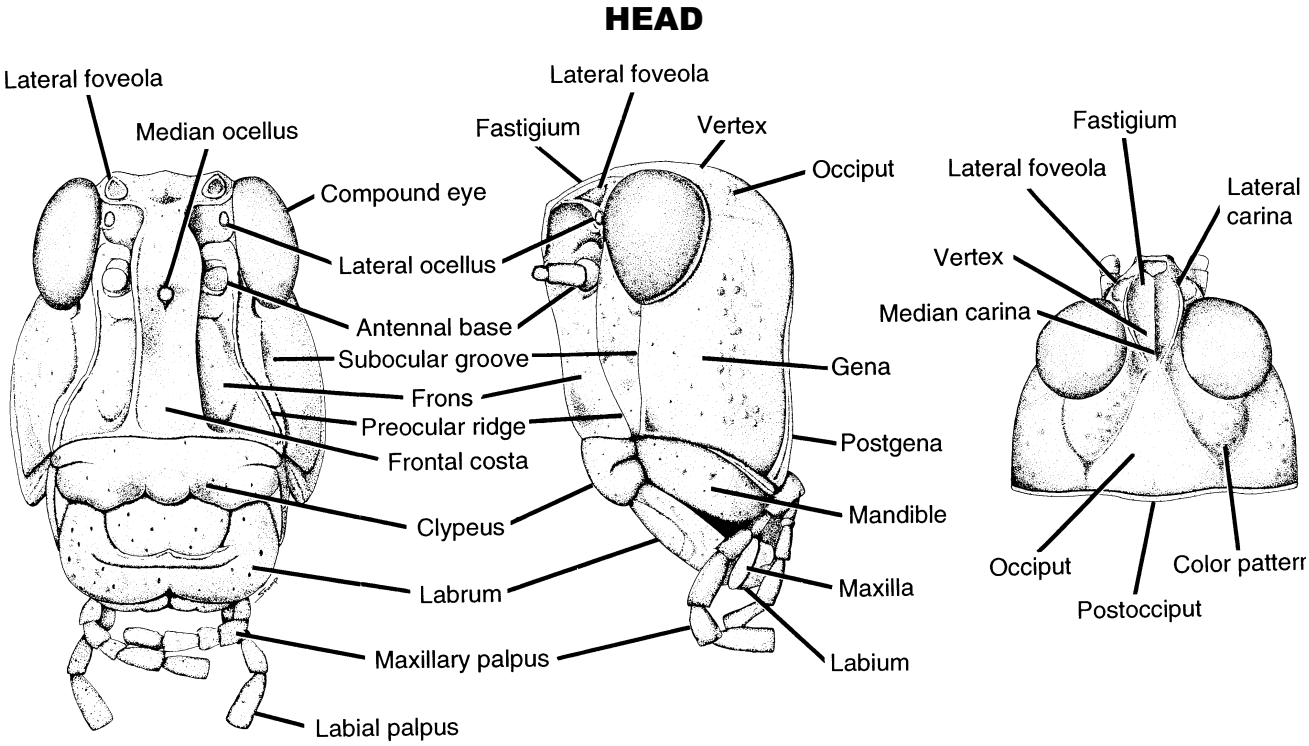

Figure 3. Grasshopper head, front, side, and top views. Modeled after *Trimerotropis pallidipennis* (Burmeister).

tracheal system for breathing, three pairs of legs, and two pairs of wings. Within the Insecta, grasshoppers belong to the order Orthoptera, as they grow and develop by gradual metamorphosis (eggs-nymphs-adults), and they have chewing mouthparts and leathery forewings called tegmina. Grasshoppers may next be placed in the family Acrididae because they possess short antennae and ovipositor (egg-layer), an auditory organ (tympanum visible externally) on each side of the first abdominal segment, and three-segmented tarsi (feet). See Table 1 summarizing the affiliation of the Carolina grasshopper, *Dissosteira carolina* (Linnaeus).

For placing grasshoppers in lower categories of classification, that is, in genus and species, one must resort to finer structures of their external anatomy and also to body size, shape, color, stripes, and patterns. Anatomical structures often have special names that the scout must learn in order to understand the descriptions of species in this guide.

Head

The head of the grasshopper is a hard capsule that contains large muscles, which operate the chewing mouthparts, and the brain and subesophageal ganglion, which serve as the main centers of the nervous system. Prominent on the outside of the capsule are a pair of antennae, two large compound eyes, and the downward directed mouthparts. The antennae of grasshoppers are usually filiform (thread-like) but they may have other shapes, such as ensiform (broad at base, narrowing to tip) or clavate (expanded at tip) (Fig. 2). Compound eyes vary in shape and protuberance. They are usually somewhat round but may be elliptical in grasshoppers with strongly slanted faces.

The head capsule is divided into areas by visible sutures, external ridges (carinae), or by general location (Fig. 3). The top of the head between the compound eyes is known as the **vertex**. Behind the vertex is the **occiput**, and in front of the vertex is the **fastigium**. A pair of variously shaped depressions, the **lateral foveolae**, is often present in front or at the sides of the fastigium. The front of the head between the compound eyes and extending to the clypeus is known as the **frons**. A wide ridge, the **frontal costa**, runs down the middle of the frons from the fastigium toward the margin of the clypeus. The side of the head below the compound eye is named the **gena** or cheek. Grasshoppers have three simple eyes called **ocelli** — one above the base of each antenna and one centrally located in the frontal costa. These and other parts and appendages of the head are illustrated in Figure 3.

Thorax

The thorax, locomotion center of the grasshopper, is a stout, boxlike structure consisting of three fused segments: the **prothorax**, **mesothorax**,

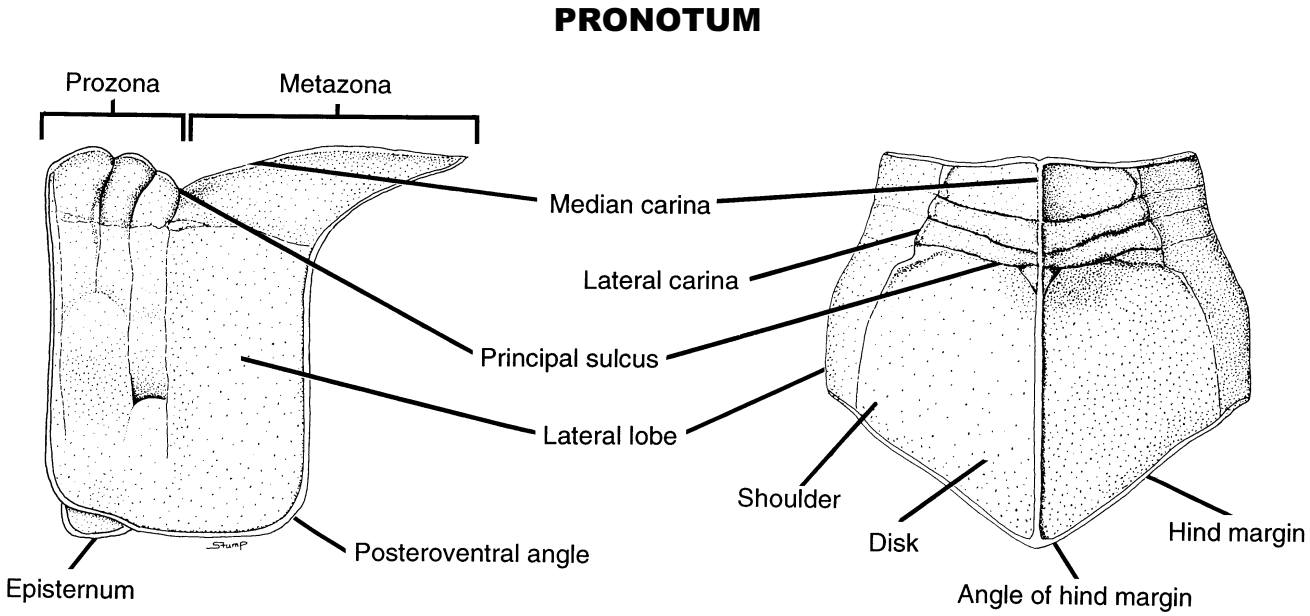

Figure 4. Grasshopper pronotum, side and top views. Modeled after *Trimerotropis pallidipenni*s (Burmeister).

and **metathorax**. Each segment bears a pair of legs. The second segment bears a pair of forewings, the **tegmina**, and the third segment a pair of membranous hindwings. The wings of a few species are reduced to small pads or are entirely lacking. The top of the thoracic segments is called the **notum**, the bottom the **sternum**, and the sides the **pleura**.

The **pronotum** situated just behind the head is a prominent, saddle-shaped structure with lateral lobes that hide nearly all of the propleura (Fig. 4). The pronotum has many distinctive features useful in separating both genera and species of grasshoppers. The integument (skin) may be nearly smooth in some species and rough and wrinkled in others. The dorsum or ***disk*** of the pronotum is divided into left and right halves by a longitudinal ridge, the **median carina**. The ridge varies among species from barely visible to a conspicuously high crest. Transverse furrows run across the disk and down the lateral lobes. These furrows, known as **sulci**, cut into the median carina and divide the disk into zones, the **prozona** in front and the **metazona** in the rear. In many species only one sulcus cuts the median carina while in others two or three sulci cut the median carina. The hind sulcus is considered the **principal sulcus**; from its position the length of the prozona and metazona are measured.

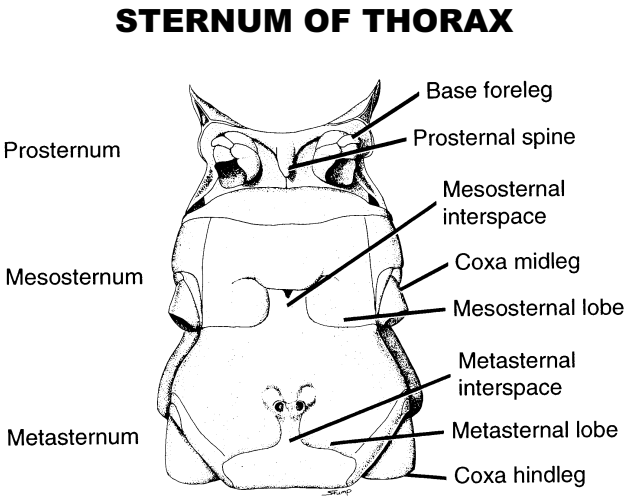

Figure 5. Sternum of thorax, bottom view. Modeled after *Melanoplus bivittatus* (Say) female.

The lateral lobes usually form an angle with the disk and are separated from the disk by lateral carinae that, depending on the species, may be straight and parallel or variously incurved or outcurved. The hind margin of the disk varies from an acute angle to an obtuse angle, or may be convex, truncate, or emarginate.

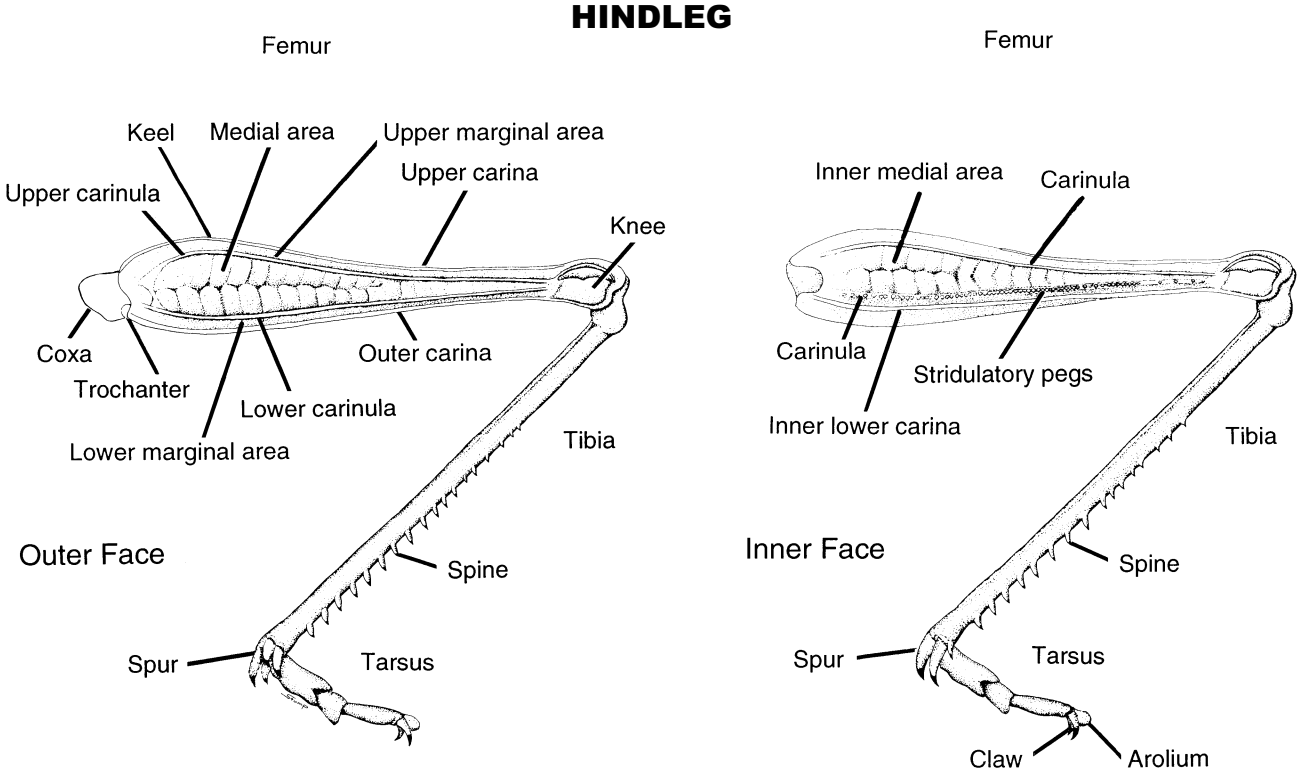

Figure 6. Grasshopper hindleg, views of outer and inner faces. Hindleg of *Mermiria bivittat*a (Serville).

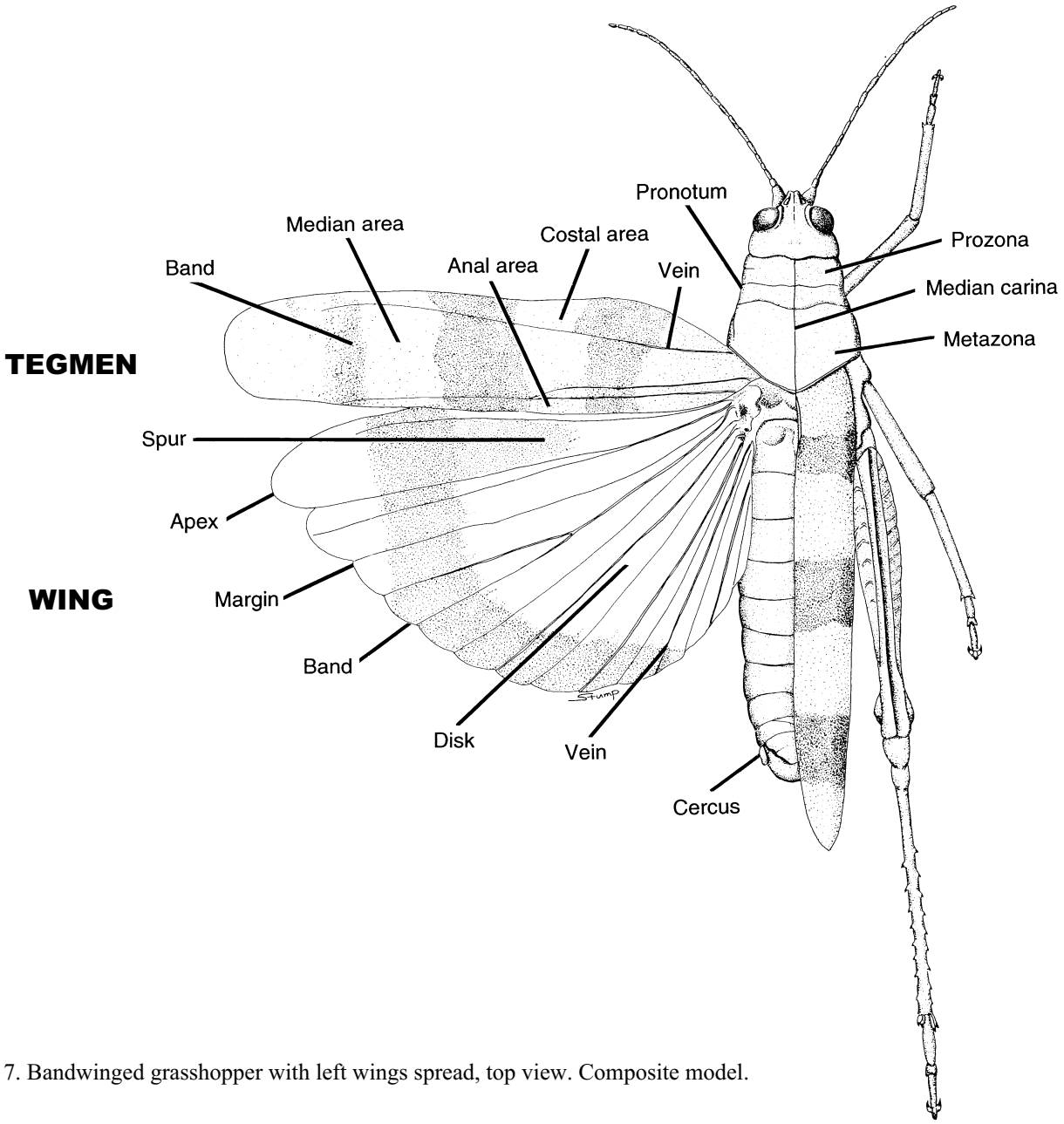

Figure 7. Bandwinged grasshopper with left wings spread, top view. Composite model.

The various shapes, sizes, and protuberance of the sternal sclerites afford reliable taxonomic characters (Fig. 5). A **prosternal spine** located between the bases of the front legs is characteristic of members of the spurthroated subfamily. Shapes and dimensions of the mesosternal and metasternal lobes and interspaces are useful in separating certain species and subfamilies.

Legs

Although the three pairs of legs have the same component parts, the hind pair, adapted for jumping, are much larger than the first and second pair and bear more distinctive features. The color and markings of both the femur and tibia differ among species. The robust **femur** has several surfaces and ridges that have been given names for easy reference (Fig. 6).

The long and slender **tibia** bears along its posterior edges a double row of spines and distally two pairs of articulated **spurs** or calcars. The number of spines and the length of calcars vary among species. The inner medial area of the femur may have a longitudinal ridge bearing a series of **stridulatory pegs**. Up and down movements of the hindlegs cause the pegs to scrape against a raised vein on each tegmen, which produces a song or signal peculiar to that species of grasshopper.

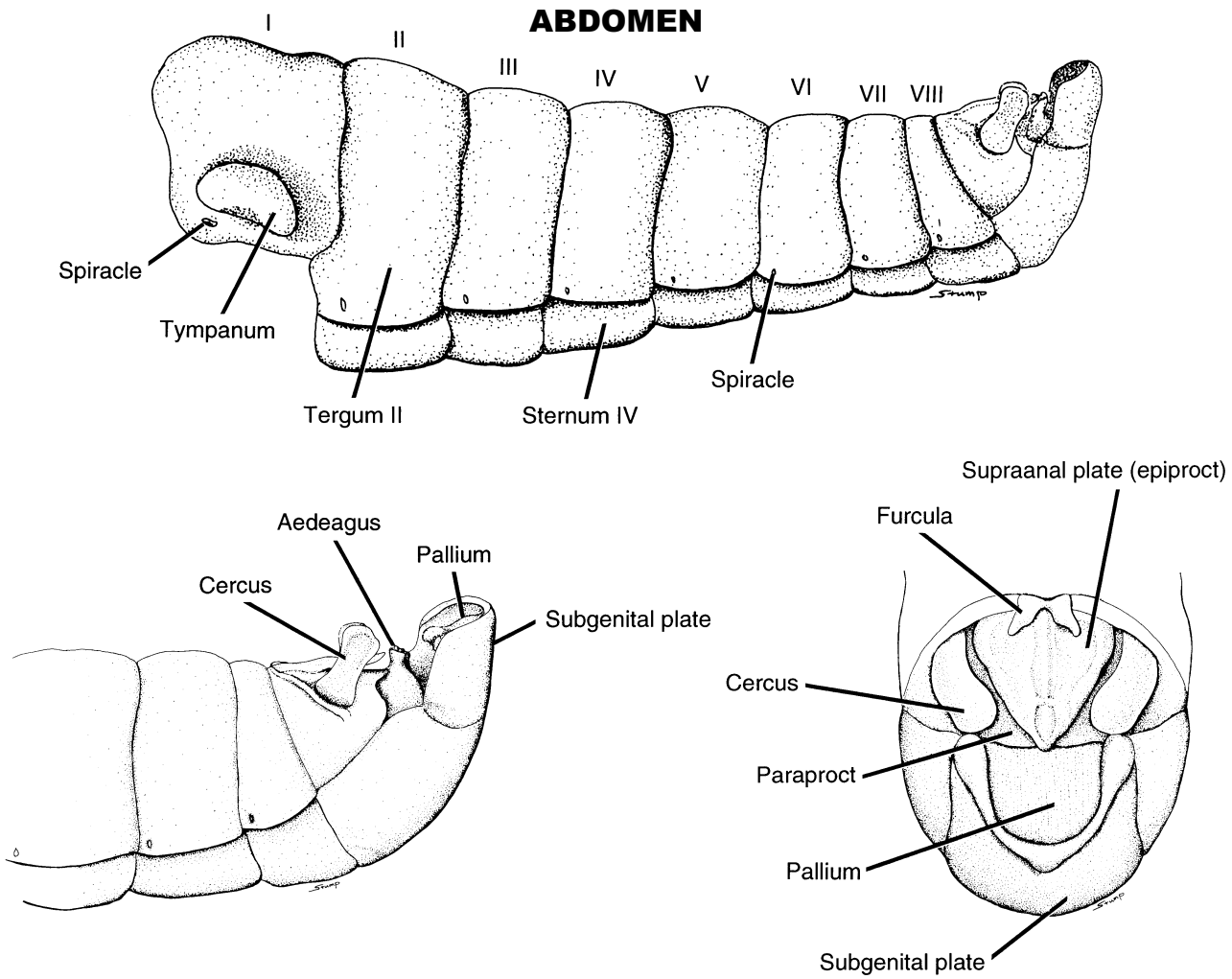

Figure 8. Grasshopper male abdomen, side view and enlarged side and dorsal views of end. Modeled after *Melanoplus packardii* Scudder.

Wings

The two pairs of grasshopper wings differ in shape, structure, and function (Fig. 7). The front pair, or **tegmina**, are leathery and narrow with the sides nearly parallel. The **hind wings** are membranous and fan-shaped. Compared with the tegmina, the hind pair contribute three times as much to flight lift. Both pairs afford diagnostic characters that aid in the identification of species. The **wing veins**, sclerotized tubes providing strength to the wings, vary greatly in thickness. The tegmina vary from immaculate to distinctly spotted or marked. The hindwings of grasshoppers are usually hyaline. Members of one subfamily, the Oedipodinae or bandwinged grasshoppers, have wings with a dark submarginal band and have the disk colored.

Abdomen

The hind region of the grasshopper's body, the abdomen, consists of 11 segments (Fig. 1). Segment I is firmly fused with the metathorax and contains the auditory organ with its eardrum cover, the **tympanum** (Fig. 8).

Segments II to VIII are ringlike in appearance and are separated from one another by pliable membranes. Each segment has a sclerotized **tergum** that covers not only the top but also the sides of the abdomen. A sclerotized **sternum** covers the bottom. Pliable membranes separate the terga from the sterna and with the intersegmental membranes allow the abdomen much flexibility, a requirement for respiratory movements, copulation, and oviposition.

Genitalia

The terminal segments of the abdomen are reduced and modified to bear the external reproductive organs, the genitalia, and the associated structures (Fig. 8). These structures offer the most reliable taxonomic characters for separating spurthroated grasshoppers. Structures of the male are more distinctive than those of the female. The prominent paired **cerci** are usually conical, but in the males of some genera, e.g. *Melanoplus*, they have characteristic sizes and shapes. Likewise, the **furcula**, a pair of projections from the posterior edge of tergum X of males, differs in size and shape. The **epiproct** or **supraanal plate**, although roughly triangular, varies sufficiently in shape and rugosity to be taxonomically useful. The variations in shape and protuberances of the **subgenital plat**e are also useful in identification. These structures are easily seen with a pocket magnifier of 10x magnification. A few distinctive structures, such as the lobes of the **aedeagus**, require the use of a stereomicroscope (magnification of 50x and greater) for clear identification.

The **valves** of the ovipositor are sometimes useful in separating species (Fig 1). The dorsal and ventral pair of valves have various shapes and denticulations. The middle pair of valves are small and hidden.

The sclerotized integument of the abdomen varies in color, patterns, and texture among species and sometimes affords distinguishing taxonomic characters.

Nymphal Characters

Identification of grasshopper nymphs presents greater difficulties because of the absence of several reliable taxonomic characters of the adult stage. In nymphs, the wings are lacking and the genitalia are undeveloped and generalized. Sets of characters, however, are useful in identifying nymphs of the three large subfamilies of western grasshoppers. The chief characters diagnostic of slantfaced nymphs

TABLE 1. Affiliation of the Carolina grasshopper, *Dissosteira carolina* (Linnaeus), with the categories of taxonomic hierarchy and the associated characteristics.

CATEGORY	TAXON	CHARACTERISTICS
Kingdom	Animalia	Sensitivity, voluntary movement, require oxygen and organic food, fixed organs.
Phylum	Arthropoda	Ringlike segments, jointed appendages, exoskeleton.
Class	Insecta	Three body regions, three pairs legs, one pair antennae, tracheal system, usually two pair wings.
Order	Orthoptera	Forewings leathery, hindwgins membranous, chewing mouthparts, hindwings enlarged for jumping, simple metamorphosis.
Family	Acrididae	Short antennae, short ovipositor, tympanum on first abdominal tergum, three segmented tarsi.
Genus	*Dissosteira*	High median pronotal crest deeply cut by one sulcus, body slender, medium to large size.
Species	*carolina*	Hindwings black with yellow margin; tegmina unicolorous or faintly spotted.

(Gomphocerinae) consist of the degree of facial slope, general color pattern, shape of the antennae and foveolae, and the extent of curving of the lateral carinae of the pronotum. Chief characters diagnostic of bandwinged nymphs (Oedipodinae) are: (1) height of the median carina of the pronotum and number of sulci; (2) position and length of the lateral carinae; (3) color patterns of the hindlegs; (4) variations in dark bands on the head and pronotum; and (5) shape of the foveolae. Chief characters diagnostic of spurthroated nymphs (Melanoplinae) are color patterns of the hind femur, color patterns of the gena and pronotum, and markings of the compound eyes. The characters of the compound eyes, namely, color, stripes, and number and size of spots, are evident in fresh specimens, but they disappear in specimens that have been held for any length of time, even frozen ones. In treatment of the individual species later on, the particular diagnostic characters of each are described and explained.

Scientific and Common Names

Grasshoppers have been collected, studied, and named from all but the most frigid regions of the earth. More than 10,000 species have been classified and given scientific names. These are binomials, a method of naming used by the Swedish biologist, Carolus Linnaeus (1707-78) in his book, S*ystema Naturae*. The method proved so successful that other biologists promptly adopted it. The tenth edition of *Systema Naturae* (1758) has been designated as the official beginning for zoological nomenclature. This classic book contains an account of the widely distributed North American grasshopper, *Dissosteira carolina* (Linnaeus).

In addition to the scientific name, species of grasshoppers may have good common names. Some are approved by the Entomological Society of America, such as the Carolina grasshopper for *D. carolina*. Nevertheless, in searching the literature and in communicating information on species of grasshoppers, the scientific name has an unrivaled advantage. All of the known species have scientific names while only a small fraction have generally accepted common names.

The **scientific name** of a species consists of two parts. The first is the name of the genus, a taxonomic category containing a group of closely related species. The second part is the specific epithet or species name. For example, *Dissosteira* is the name of the grasshopper genus that contains four species; *carolina* is the specific epithet of one of the four species. The two words together, *Dissosteira carolina*, comprise the scientific name of the Carolina grasshopper. After the two words the name of the describer, Linnaeus, provides extra information. Linnaeus' name is in parenthesis, which means that originally Linnaeus had placed this species in a different genus (*Gryllus*) and another taxonomist later revised the scientific name by placing the species in a new or different genus. A describer who has assigned a newly described species to an established genus is not named in parentheses, for example *Melanoplus confusus* Scudder.

The scientific name is always italicized. After it has been written in full once, it is usually abbreviated by using the initial of the genus, followed by the full spelling of the epithet, and the dropping of the describer's name, hence *D. carolina*. The first letter of the genus name is always capitalized and the first letter of the specific epithet is always lower case. The genus name may be used alone when referring to the genus only or to all of the species making up the genus such as *Dissosteira* or *Melanoplus*.

How do taxonomists choose a scientific name for a species new to science? Rules of Latin grammar must be followed but otherwise there is much latitude in selecting a name. If the new species can be assigned to a valid genus, a specific epithet not already in use within the genus is chosen. The name may describe a character of the grasshopper or locate the region or state where it was collected. Or it may honor a friend or a renowned scientist. For example, in a taxonomic study published in 1897, Samuel Scudder named a new species *Melanoplus bruneri* in honor of professor Lawrence Bruner, a pioneer grasshopper specialist at the University of Nebraska, Lincoln. To be a valid scientific name, the author must publish the description and name of a new species in a journal article, bulletin, or book.

As a finishing touch in establishing the authenticity of a new species, the describer chooses a particular specimen as the **type** or holotype. In the taxonomy of grasshoppers, the type selected by the author is an adult male from which the original description and illustrations were made. A female specimen is also chosen for description and illustration and is specified as the **allotype**. The author uses other specimens, termed material, for comparison with the types, often describing slight differences in size and color. These may be designated as **paratypes**, both males and females.

The taxonomist must also decide on the deposition of the types in an insect museum. If the author is a member of the staff of a particular museum, the types are usually deposited with that museum. In cases where the author is not employed by a museum, the types are sent to a recognized museum. Many grasshopper types are held in the extensive collections of the Academy of Natural Sciences of Philadelphia, the California Academy of Sciences (San Francisco), the Museum of Zoology, University of Michigan (Ann Arbor), the Lyman Entomological Museum (Ste. Anne de Bellevue, Quebec), and the National Museum of Natural History (Washington, DC). These are favored museums for the deposition of grasshopper types. The author may send the types to one museum and paratypes to the others and, if there is sufficient material, still other specimens to smaller museums.

Although the grasshopper fauna of North America is relatively well known, new species continue to be found in all parts of the continent and to be described in entomological publications. The chance is slim, however, that a scout will pick up a new species where grasshopper infestations occur. In most instances the scout will be able to identify a specimen from the pages of this field guide. On occasion a scout may collect an already described species not treated in the guide, particularly in genera with large numbers of species such as *Melanoplus* and *Trimerotropis*. The scout may then resort to a state grasshopper "key" (see Selected References).

Species

What are species? *Species* in Latin merely means "kind" and so species in an elementary sense are different kinds of organisms. Most, if not all, species of grasshoppers can be distinguished on the basis of obvious anatomical and behavioral characters and are biological realities. In nature, species consist of populations of individuals that usually occur over an extensive geographic range. For this reason one modern view considers a species to be a genetically distinctive group of natural populations that share a common gene pool and are reproductively isolated from all other such groups. The species is the largest unit of population within which effective gene flow occurs or can occur. Higher taxonomic categories, from the genus up, are biologists' inventions that exist only in the human mind. Animals in the same category have anatomical similarities showing clear relationships. Their grouping, however, is a decision based on a mix of objective and subjective evaluations. One taxonomist's family can easily be another's order.

Grasshopper Populations

Grasshopper infestations or assemblages consist of the individuals of several species that live together in the same habitat sharing or competing for available food and space. Members of the dominant species outnumber members of other species and may make up more than 50 percent of the assemblage. Occasionally two or three species may become codominants. No evidence has been found for any essential relationship among species that brings them together. The habitat affords the minimum requirements for all the permanent species and ample measure for the abundant.

Grass-feeding species of grasshoppers are the most numerous in grasslands. In a northern mixedgrass prairie site 18 miles northwest of Fort Collins, Colorado, a total of 24 species were recorded during an outbreak in 1981 (Table 2). Of the total, 14 were grass feeders, six were mixed feeders, and four were forb feeders. The number of individuals of grass-feeding species made up 85% of the total population. The dominant grasshopper, *Ageneotettix deorum* (Scudder), contributed 52% of the population. A second example of an outbreak population in northern mixedgrass prairie was the assemblage inhabiting a site 15 miles north of Hartville, Wyoming, where 16 species were recorded (Table 2). Nine species were grass feeders, one a mixed feeder, and six were forb feeders. The number of individuals of grass feeding species made up 89% of the population. The dominant grasshopper, *Aulocara elliotti* (Thomas), contributed 74% of the population.

Why was *A. deorum* dominant in one mixedgrass prairie site and *A. elliotti* dominant in another? And why was *Cordillacris occipitalis* (Thomas) the second most abundant in one site and entirely missing from the other? Answers to these questions are not available. An hypothesis for the cause of the observed variations in densities was the differences in habitat in conjunction with differences in requirements of the grasshoppers. Although both sites are part of the northern mixedgrass prairie, the soil, slope, and vegetation of each differ significantly. Grasshopper species vary in densities and dominance depending on the soil, vegetation, topography, and use of a habitat. Because of differential effects of weather, parasites, disease, or insecticidal

TABLE 2. Number and density of grasshopper species in mixedgrass prairie and in desert grassland.

	NUMBER/SQ YD		
	Mixedgrass Colorado	**Mixedgrass Wyoming**	**Desert grass Arizona**
Gomphocerinae			
Aeropedellus clavatus	0.2	2.2	
Ageneotettix deorum	26.3	1.4	0.2
Amphitornus coloradus	3.9	0.2	0.3
Aulocara elliotti	2.8	20.7	18.0
Aulocara femoratum	0.3		
Boopedon nubilum			0.2
Cordillacris crenulata		0.2	
Cordillacris occipitalis	4.0		
Eritettix simplex	+		0.2
Opeia obscura	1.6		
Philbostroma quadrimaculatum	0.9		
Psoloessa delicatula	0.1	0.3	0.5
Oedipodinae			
Arphia pseudonietana	0.02		
Camnula pellucida		0.2	
Hadrotettix trifasciatus		0.2	2.5
Mestobregma plattei			0.2
Metator pardalinus	0.3	2.5	1.8
Spharagemon equale	0.2		
Trachyrhachys kiowa	2.5		
Trimerotropis pallidipennis			0.9
Xanthippus corallipes	0.003	0.1	0.2
Melanoplinae			
Hesperotettix viridis	0.2	0.2	
Melanoplus bivittatus	0.1		
Melanoplus confusus	0.2	0.2	
Melanoplus cuneatus			20.9
Melanoplus packardii	0.6	0.2	
Melanoplus fladstoni	0.5		
Melanoplus infantilis	1.2	0.3	
Melanoplus keeleri	0.3		
Melanoplus occidentalis	1.5	1.8	
Melanoplus sanguinipes	2.8	0.6	6.0
Total grasshoppers /sq yd	50.5	31.3	51.9
Number species	24	16	13

+ indicates species present but not recorded in sampling

treatments, the densities of grasshopper species inhabiting a rangeland site may change with time. The abundant species, however, tend to retain their dominant status over the years.

The composition of grasshopper assemblages is characteristic of various grassland types. A scout working in a western state expects particular species to compose economic infestations in certain areas. Table 3 lists species abundant in several grassland types and in disturbed land (crop borders, fence rows, reversions, roadsides). Because the species composition of grasshopper assemblages infesting particular habitats remains almost the same year after year, a scout is aided in identifying nymphs by knowing the species that were present as adults during past years. Widespread species with high biotic potential, such as *Aulocara elliotti* and *Ageneotettix deorum*, inhabit many grassland types and become abundant members in various assemblages of grasshoppers. In outbreaks on desert grasslands of Arizona and New Mexico, for example, *A. elliotti* is often the dominant species (Table 2), as in many infestations of the northern mixedgrass prairie.

Life History

There are probably as many grasshopper life histories as there are grasshopper species. Each species appears to possess a unique set of ecological and physiological adaptations that allow it to grow, survive, and reproduce in its environment. The habitat furnishes individuals with nutritive food plants, adequate living space, satisfactory soil conditions for the eggs, and favorable or tolerable physical and biotic relationships for all the life stages. Because of the distinctive habits and behaviors of grasshoppers, the particular facts of their life histories will be discussed later in treatment of the individual species.

Life Cycle

All grasshoppers begin their lives as eggs. Yet eggs represent the least known stage of the grasshopper life cycle. They are laid in the soil of the habitat and develop hidden from the view of humans. Eggs of a few species, however, have been studied in both field and laboratory (Fig. 9). Incubation of eggs begins immediately after females deposit them in the soil. The embryo, at first a tiny disc of cells laying on the ventral side of the yolk surface and at the posterior end of the eggs (Fig. 10),

Figure 9. One intact and one broken egg pod, exposing the eggs of the migratory grasshopper, *Melanoplus sanguinipes* (Fabricius).

grows rapidly, receiving nourishment from the nutrient stores in the yolk.

In seven days the embryo of the migratory grasshopper, *Melanoplus sanguinipes*, held at an incubation temperature of 30½C, reaches Stage 19. In this stage the embryos of many rangeland species such as *Aulocara elliotti* and *Camnula pellucida* cease growth and begin a **diapause**. The embryo of the migratory grasshopper, however, continues to develop and at Stage 20 actively moves from the ventral to the dorsal surface and revolves 180½ on its long axis (see Figure 10, Stage 20). After 15 days the embryo has grown to Stage 24, having achieved 80 percent of its development. It then ceases growth and enters diapause. The embryo of the twostriped grasshopper, and probably others also, enter diapause at this stage. Exposed to favorable incubation temperatures, the eggs of a few rangeland species, such as *Arphia conspersa* and *Xanthippus*

TABLE 3. Common species of grasshoppers found in several grassland types, in cold desert shrub, and in distrubed land.

Tallgrass prairie

Ageneotettix deorum
Melanoplus bivittatus
Melanoplus differentialis
Melanoplus femurrubrum
Orphulella speciosa
Phoetaliotes nebrascensis
Syrbula admirabilis

Northern mixedgrass prairie

Aeropedellus clavatus
Ageneotettix deorum
Amphitornus coloradus
Aulocara elliotti
Aulocara femoratum
Camnula pellucida
Cordillacris occipitalis
Encoptolophus costalis
Melanoplus infantilis
Melanoplus sanguinipes
Opeia obscura
Phlibostroma quadrimaculatum
Psoloessa delicatula

Southern mixedgrass prairie

Ageneotettix deorum
Amphitornus coloradus
Aulocara elliotti
Boopedon nubilum
Melanoplus sanguinipes
Mermiria bivittata
Opeia obscura
Orphulella speciosa
Phlibostroma quadrimaculatum

Bunchgrass prairie

Aulocara elliotti
Conozoa sulcifrons
Cordillacris occipitalis
Dissosteira spurcata
Melanoplus sanguinipes
Oedaleonotus enigma
Trimerotropis pallidipennis

Shortgrass prairie

Cordillacris crenulata
Hadrotettix trifasciatus
Melanoplus gladstoni
Opeia obscura
Trachyrhachys aspera
Trachyrhachys kiowa

Desert prairie

Ageneotettix deorum
Amphitornus coloradus
Aulocara elliotti
Hadrotettix trifasciatus
Melanoplus cuneatus
Melanoplus sanguinipes
Trimerotropis pallidipennis

Mountain meadows

Aeropedellus clavatus
Anabrus simplex
Amnula pellucida
Chorthippus curtipennis
Melanoplus alpinus
Melanoplus borealis
Melanoplus bruneri
Melanoplus dawsoni
Melanoplus sanguinipes
Stenobothrus brunneaus

Sand prairie

Ageneotettix deorum
Melanoplus angustipennis
Melanoplus flavidus
Melanoplus foedus
Mermiria bivittata
Opeia obscura
Phoetaliotes nebrascensis

Annual grassland

Camnula pellucida
Dissosteira pictipennis
Dissosteira spurcata
Melanoplus devastator
Melanoplus marginatus
Melanoplus sanguinipes
Oedaleonotus enigma

Cold desert shrub

Aulocara elliotti
Cordillacris occipitalis
Dissosteira spurcata
Melanoplus rugglesi
Oedaleonotus enigma
Trimerotropis pallidipennis

Disturbed land (reversions, roadsides, crop borders)

Aeoloplides turnbulli
Dissosteira carolina
Melanoplus angustipennis
Melanoplus bivittatus
Melanoplus differentialis
Melanoplus femurrubrum
Melanoplus lakinus
Melanoplus packardii
Melanoplus sanguinipes

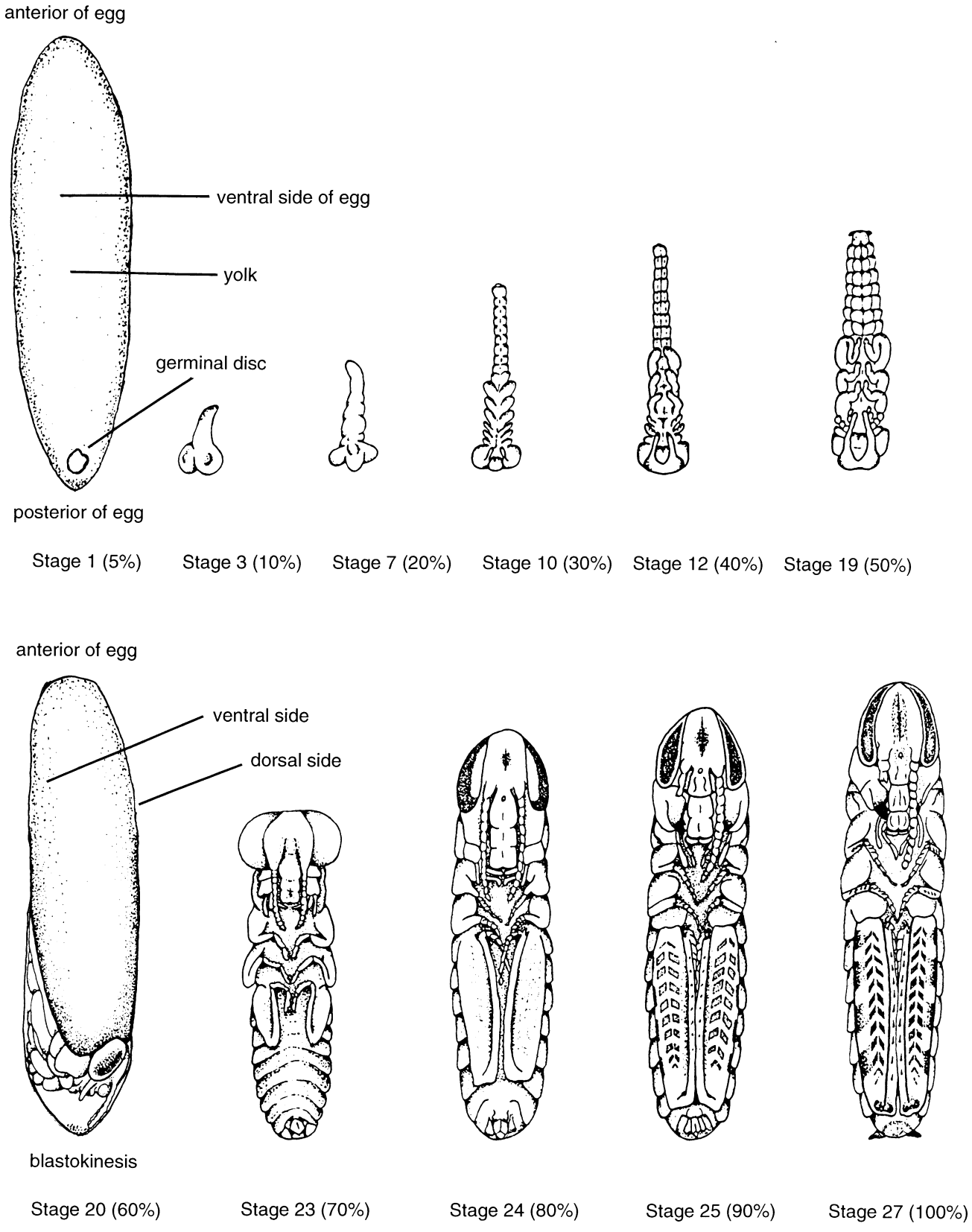

Figure 10. Selected stages in the development of a grasshopper embryo (*Melaoplus sanguinipes*) held at a constant temperature of 30 C. Left two figures show whole egg; other figures show embryos removed from egg. (Illustrations adapted from Riegert, 1961; stages identified and designated for embryos of *Aulocara elliotti* by Saralee Visscher, 1966).

corallipes, develop completely and hatch during the same summer they are laid. The immediate cause of cessation of embryonic growth (diapause) in eggs of the majority of rangeland grasshoppers appears to be the shutdown of growth hormones. The embryos remain physiologically active as transfer of nutrient materials from the yolk into the embryonic fat body and other tissues continues. Cold temperatures of winter, however, slow or end this process and embryos enter a dormant period.

For eggs laid in temperate regions to reach their maximum development before diapause, they must receive sufficient heat, usually measured as day-degrees of heat accumulated in the soil at egg depth. Eggs deposited late in the season or during a cold summer may not receive this amount of heat, especially in northern areas such as the Canadian provinces of Alberta, Manitoba, and Saskatchewan. Eggs that do not reach their potential stage of development have reduced hatchability the following spring and thus do not contribute as much to the maintenance of a population.

During winter, low ground temperatures eventually break egg diapause. As soon as the ground warms above threshold soil temperatures of 50 to 55½F in spring, the embryos are ready to continue their development. Research has shown that for the few species studied, eggs need 400 day-degrees by fall to attain maximum embryonic growth and another 150 day-degrees in spring to initiate hatching. For completion of embryonic growth from start to finish, eggs require totals of 500 to 600 day-degrees.

In spring the emergence of hatching grasshoppers may be readily observed. All embryos of a single pod usually wriggle out one after another within several minutes. Once out, they immediately shed an embryonic membrane called the serosa. An individual hatchling, lying on its side or back and squirming, takes only a few minutes to free itself (Fig. 11). During this time the hatchlings are susceptible to predation by ants. After the shedding of the membrane the young grasshoppers stand upright and are able to jump away and escape attacking predators. In spring, young grasshoppers have available green and nutritious host plants. The majority of individuals in grasslands are grass feeders, but individuals of some species are mixed feeders, eating both grasses and forbs. Others are strictly forb feeders.

As insects grow and develop, they molt at intervals, changing structures and their form. This process is called metamorphosis. A number of insects undergo gradual (simple) **metamorphosis**, such as grasshoppers. With this type of metamorphosis the insect that hatches looks like the adult except for its smaller size, lack of wings, fewer antennal segments, and rudimentary genitalia (Fig. 11). Other insects with gradual metamorphosis include the true bugs, aphids, leafhoppers, crickets, and cockroaches. The majority of insects undergo complete (complex) metamorphosis, as the eggs hatch into wormlike larvae adapted for feeding and have a vastly different appearance from that of the adult insect. Before full-grown larvae can become adult insects they must enter into the pupal stage. In this stage they develop and grow the adult structures. Common examples of insects that undergo complete metamorphosis are beetles, butterflies, bees, wasps, and flies.

For young grasshoppers to continue their growth and development and reach the adult stage, they must periodically molt or shed their outer skin (Fig. 11). Depending on species and sex, they molt four to six times during their nymphal or immature life. The insect between molts is referred to as an instar; a species with five molts thus has five instars. After shedding the serosal skin, the newly hatched nymph is the first instar. After each molt the instar increases by one so that the nymph consecutively becomes a second, third, fourth, and fifth instar. When the fifth instar molts, the grasshopper becomes an adult or an imago.

The new adult has fully functional wings but is not yet ready to reproduce. The female has a preoviposition period of one to two weeks during which she increases in weight and matures the first batch of eggs. Having mated with a male of her species, the female digs a small hole in the soil with her ovipositor and deposits the first group of eggs. Once egg laying begins, the female continues to deposit eggs regularly for the rest of her short life. Depending on the species, production may range from three pods per week to one pod every one to two weeks. The species that lay fewer eggs per pod oviposit more often than those that lay more eggs per pod.

The egg pods of grasshoppers vary not only in the number of eggs they contain but also in their size, shape, and structure. Based on structure, four types have been recognized. In type I a stout pod

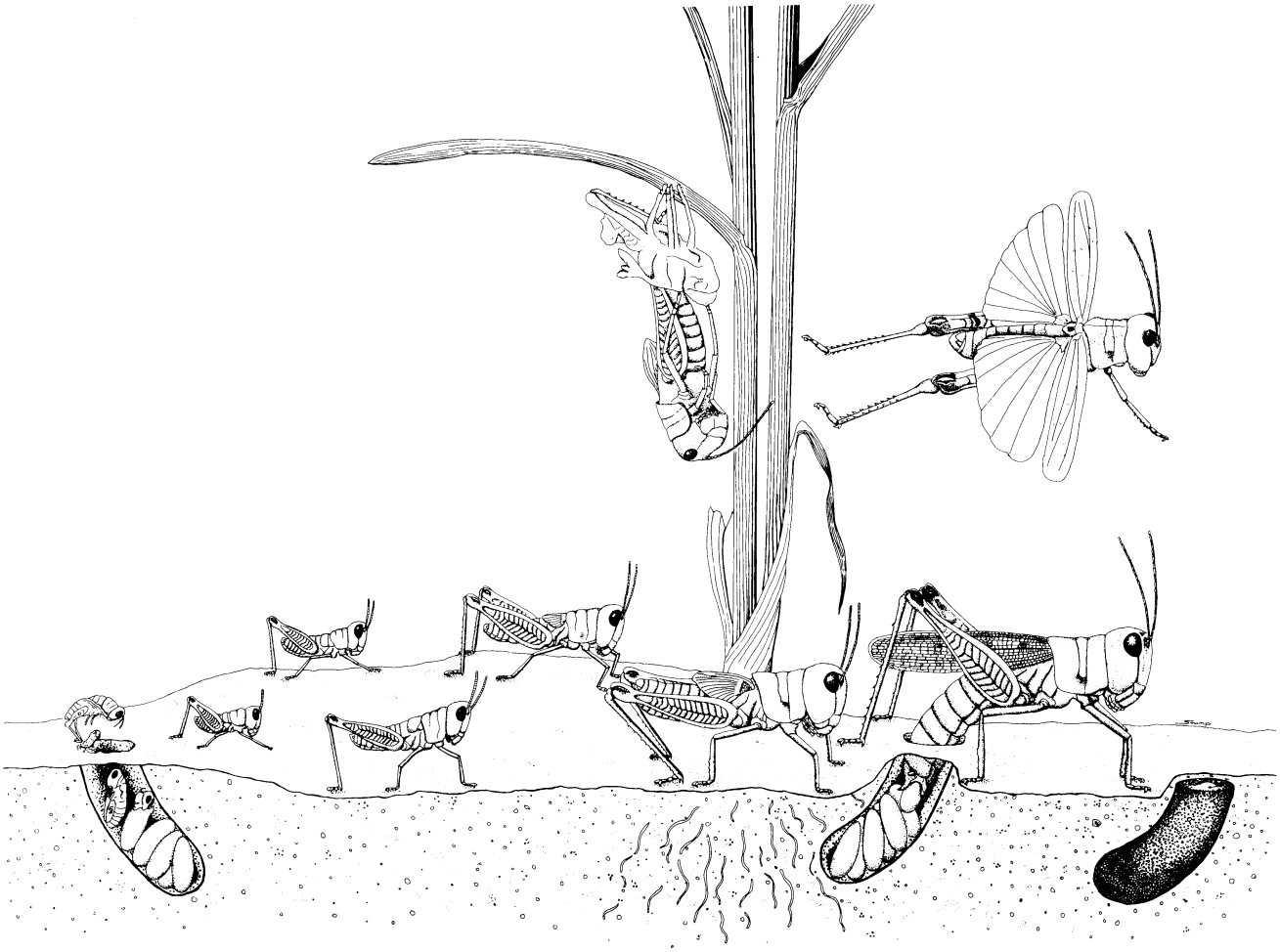

Figure 11. The lifecycle of the bigheaded grasshopper, *Alucara ellliotti* (Thomas). During summer in bare spots of grassland the female deposits at intervals batches of eggs. As soon as the eggs are laid, they begin embryonic development and reach an advanced stage in which they enter diapause and pass the winter. In spring the eggs complete embryonic development and hatch. The young grasshopper sheds a serosal skin, the exoskeleton hardens, and the nymph begins to feed and grow. After molting five times and developing through five instars in 30-40 days, it becomes an adult grasshopper with functional wings. The adult female matures groups of six to eight eggs at a time and deposits them in the soil at intervals of three to four days for the duration of her short life.

forms from frothy glue and soil surrounding the eggs; froth is lacking between the eggs. In type II a weaker pod is formed from frothy glue between and surrounding the eggs. In type III frothy glue is present between the eggs but does not completely surround them. In type IV only a small amount of froth is secreted on the last eggs of a clutch, and most of the eggs lie loosely in the soil. Grasshopper eggs themselves vary in size, color, and shell sculpturing. Depending on the species eggs range from 4 to 9 mm long and may be white, yellow, olive, tan, brownish red, or dark brown. Eggs of certain species are two-toned brown and tan.

Events in the life cycle of an individual species of grasshopper — hatching, nymphal development, and adulthood — occur over extended periods. The eggs may hatch over a period of three to four weeks. Nymphs may be present in the habitat eight to ten weeks and adults nine to 11 weeks. Because of the overlapping of stages and instars, raw field data obtained by sampling populations do not answer several important questions. For example, how many

eggs hatched? How many individuals molted successfully to the next instar? What was the average duration of each instar? How many became adults? What was the average length of life and the average fecundity of adult females? To obtain answers to these questions, detailed sampling data must be treated mathematically.

Laboratory data may also be used in studying grasshopper life histories. Table 4 provides information on the life history of the migratory grasshopper, *Melanoplus sanguinipes*, reared at a constant temperature of 86½F and 30-35% relative humidity and fed a nutritious diet of dry feed, green wheat, and dandelion leaves. The entire nymphal period averages 25 days for males and 30 days for females. Each instar takes four to five days to complete development except for the last instar, which takes seven days. Adult longevity of males averages 51 days and females, 52 days. Longevity of adults in the field is no doubt briefer because of the natural predators and parasites cutting short the lives of their prey.

TABLE 4. Life history of the migratory grasshopper, *Melanoplus sanguinipes*, reared in the labratory at a constant temperature of 86²F.

	DAYS	
Stage	**Male**	**Female**
Instar 1	4.5	4.9
2	4.1	4.0
3	4.5	4.3
4	4.9	4.5
5	7.3	4.7
6	____	____
Total nymphal period	25.3	29.5
Average adult longevity	51.0	52.0

Seasonal Cycles

An important component of grasshopper life history is the seasonal cycle - the timing of the periods of egg hatch, nymphal growth and development, emergence of the adults and acquisition of functional wings (fledging), and the deposition of eggs or reproduction. The occurrence of these periods varies among the species and is greatly influenced by weather. An early spring hastens these events and a late one delays them. Latitude also influences the dates of occurrence. In North America springtime comes earlier in the south and later in the north. Consequently, hatching, development and maturation come earlier in the south and later in the north. In the West, altitude is also an important factor. The lower temperatures of higher altitudes, especially those of mountain meadows, are responsible for retarded seasonal cycles of grasshoppers and may often cause a two-year life cycle among species that ordinarily have a one-year life cycle.

Nymphal and adult grasshoppers are present all year long in natural habitats. Several species overwinter in late nymphal stadia and become adult in early spring. The majority, however, pass the winter as eggs protected in the soil. Depending on the species, these eggs hatch at different times from early spring until late summer. The variety of seasonal cycles allows actively feeding and developing grasshoppers to spread out over the entire growing season. Each species has its own time to hatch, develop, and reproduce, but with much overlapping of the cycles. An experienced scout going into the field to survey expects to find certain species at certain times and is thus aided in making identifications. Table 5 arranges the seasonal cycles of grasshoppers into: (1) very early nymphal and adult group, (2) very early hatching group, (3) early hatching group, (4) intermediate hatching group, and (5) late hatching group. The table is especially helpful in the identification of young nymphs.

Behavior

A grasshopper's day (and night) are linked closely with the physical factors of the environment, especially temperature, but also light, rain, wind, and soil. Stereotyped and instinctive behavior patterns serve grasshoppers remarkably well in making adjustments to wide fluctuations of physical factors that otherwise might be fatal. Grasshoppers effectively exploit the resources of their habitat and at the same time are able to tolerate or evade the extremes of physical factors. Their characteristic rapid jumping and flying responses help them escape numerous enemies that parasitize or feed upon them.

In temperate North America, certain behavior patterns are held in common among grasshopper species, especially among those occupying the same

TABLE 5. Species of grasshoppers grouped by seasoned appearances.

SLANTFACED (Gomphocerinae)	**BANDWINGED** (Oedipodinae)	**SPURTHROATED** (Melanoplinae)
Early spring, large nymphs and adults. Overwinted in nymphal stage.		
Eritettix simplex	*Arphia conspersa*	
Psoloessa delicatula	*Chortophaga viridifasciata*	
Psoloessa texana	*Pardalophora apiculata*	
	Pardalophora haldemani	
	Xanthippus corallipes	
	Xanthippus montanus	
Very early hatching group, hatching in early spring.		
Aeropedellus clavatus		*Melanoplus confusus*
Early hatching group, hatching in mid-spring.		
Acrolophitus hirtipes	*Camnula pellucida*	*Aeoloplides turnbulli*
Ageneotettix deorum	*Dissosteira pictipennis*	*Melanoplus angustipennis*
Amphitornus coloradus	*Dissosteira spurcata*	*Melanoplus bivittatus*
Aulocara elliotti	*Trimerotropis pallidipennis*	*Melanoplus cuneatus*
Cordillacris occipitalis		*Melanoplus foedus*
		Melanoplus infantilis
		Melanoplus occidentalis
		Melanoplus packardii
		Melanoplus rugglesi
		Melanoplus sanguinipes
		Oedaleonotus enigma
Intermediate hatching group, hatching in late spring.		
Aulocara femoratum	*Derotmema haydeni*	*Hesperotettix viridis*
Boopedon nubilum	*Dissosteira carolina*	*Hypochlora alba*
Chorthippus curtipennis	*Dissosteira longipennis*	*Melanoplus bowditchi*
Cordillacris crenulata	*Hadrotettix trifasciatus*	*Melanoplus dawsoni*
Mermiria bivittata	*Mestobregma plattei*	*Melanoplus devastator*
Orphulella speciosa	*Metator pardalinus*	*Melanoplus differentialis*
Parapomala wyomingensis	*Spharagemon collare*	*Melanoplus flavidus*
Phlibostroma quadrimaculatum	*Spharagemon equale*	*Melanoplus femurrubrum*
Pseudopomala brachyptera	*Trachyrhachys kiowa*	*Melanoplus marginatus*
	Trimerotropis campestris	*Brachystola magna*
Late hatching group, hatching begins in early summer.		
Eritettix simplex	*Arphia conspersa*	*Dactylotum bicolor*
Opeia obscura	*Arphia pseudonietana*	*Melanoplus alpinus*
Psoloessa delicatula	*Chortophaga viridifasciata*	*Melanoplus borealis*
Psoloessa texana	*Pardalophora apiculata*	*Melanoplus bruneri*
Stenobothrus brunneau	*Pardalophora haldemani*	*Melanoplus keeleri*
Syrbula admirabilis	*Xanthippus corallipes*	*Melanoplus lakinus*
	Xanthippus montanus	*Phoetaliotes nebrascensis*
		Schistocerca emarginata

part of the habitat, while other patterns differ. Individuals of different species have different ways of spending the cool nights. Some retreat under litter or canopies of grasses; others squat on bare ground and take no special shelter. Still others may climb a small shrub or a tall grass plant and rest at various heights within the canopy. Under favorable conditions of temperature and other elements of weather, grasshoppers may be active and even feed during the night. In southwestern states they have been observed on warm nights wandering about on the ground and on vegetation, feeding, and stridulating. Several species have been recorded flying at night and are attracted to city lights. A temperature of 80°F is apparently a prerequisite for night flying with maximum flight activity occurring at temperatures above 90°F.

A grasshopper's day usually starts shortly after dawn. Because body temperatures have fallen during the night, a grasshopper on the ground crawls to an open spot, often on the east side of vegetation, that allows it to warm itself by basking in the radiant rays of the sun. A common orientation is to turn a side perpendicular to the rays and lower the associated hindleg, which exposes the abdomen. Those that have spent the night on a plant make adjustments in their positions to take advantage of the sun's rays or they may climb or jump down to the ground to bask. Although grasshoppers generally remain quiet while they bask, they occasionally stir, preen, turn around to expose the opposite side, and sometimes crawl to a more favorable basking location. Grasshoppers may bask for a second time in the cool of late afternoon. Then as shadows begin to engulf the habitat, they retreat into their customary shelters.

After basking for one to two hours on sunny days, grasshoppers become active. They may walk about, seek mates, or feed. Because grasshoppers are cold-blooded creatures, their usual daily activities are interrupted when the weather turns cold, overcast, or rainy. During such times they generally remain sheltered and inactive.

During warm sunny weather of late spring and summer, grasshoppers take advantage of two foraging periods, one in the morning and one in the afternoon. Different species of grasshoppers have different ways of attacking and feeding on their host plants. Individuals of certain species climb the host plant to feed on leaves, petals, buds, or soft seeds while others cut and fell a grass leaf and feed on it while sitting on the ground. Geophilous (ground-dwelling) species regularly search the ground for food, picking up and feeding on seeds, dead arthropods, and leaves felled by other grasshoppers. In grasslands with considerable bare ground, very little litter is produced by grasshoppers. Severed leaves, dropped by the grasshoppers that feed on the host plant, are soon found and devoured by the ground foragers. In habitats infested by dense populations of grasshoppers, pellets of their excrement, rather than litter, accumulate in small conspicuous piles. Only in habitats of tall grass do grasshoppers produce leafy ground litter that goes uneaten and "wasted." This is because the grasshopper species in these habitats are phytophilous and feed resting on the host plant.

Grasshoppers fastidiously select their food. By lowering their antennae to the leaf surface and drumming (tapping) it with their maxillary and labial palps, grasshoppers taste a potential food plant. Gustatory sensilla located on the tips of these organs are stimulated by attractant and repellent properties of plant chemicals, allowing a grasshopper to choose a favorable host plant and reject an unfavorable one. A grasshopper may take an additional taste by biting into the leaf before it begins to feed freely. Phagostimulants are usually important ones nutritionally -certain sugars, phospholipids, amino acids, and vitamins. Grasshoppers may even make choices among the leaves of a single host plant. They prefer young green leaves and discriminate against old yellowing ones. Nevertheless, individuals of ground-dwelling species often feed in short bouts on old plant litter lying on the ground as well as on dry animal dung. This feeding may be a means of restoring water balance - either losing or gaining moisture.

Later, in the species fact sheets, grasshopper food plants are referred to by their common names. The appendix beginning on page 29 provides a listing of these with their scientific names to clarify any ambiguities.

Amazingly, grasshoppers are able to communicate visually and acoustically among themselves. They produce sounds with structural adaptations on hindlegs and wings and receive these signals with auditory organs (ears) located in the first abdominal segment (Fig. 8). Using their colorful wings and hindlegs they also flash visual messages and receive these with their compound eyes. Intraspecific communication, that which occurs between members of the same species, is used to attract and recognize mates, to ward off an unwanted suitor, and

to defend a territory or a morsel of food. Grasshoppers produce acoustical signals by rubbing the hindlegs against the tegmina (Fig. 12) or the sides of the abdomen. They may also communicate by rapidly flexing or snapping their hindwings in flight, a behavior called **crepitation**. Each species apparently produces its own unique sound and, in human terms, has its own language. The details, where known, of finding a mate are described in the species section of this guide.

Oviposition behavior differs among species of grasshoppers. Most species lay their eggs in the ground. Females of some species choose bare ground, while others choose to lay among the roots of grasses or forbs. A female ready to lay often probes the soil several times before finally depositing a clutch of eggs. Experimental evidence indicates that probing is a means by which a female obtains sensory information on the physical and chemical properties of the soil. The ovipositor is supplied with a variety of sensilla that allow a female to monitor soil conditions. Temperature of the soil must be favorable, water content must be in a suitable range, and acidity and salt content of soil must be tolerable. Females of some species select loose soils such as sand, some rocky soils, while the majority of females prefer compact loamy soils for oviposition. The pods of different species vary in size, shape, and depth in the soil. The latter condition profoundly affects incubation temperature, hatching, and egg survival.

A female actively depositing eggs is often attended by one or more males. Depending at least partly on clutch size, females take from 25 to 90 minutes to lay a full complement of eggs. After withdrawing her ovipositor a female will take a minute or two to cover the aperture of the hole with particles of soil and ground litter. The female uses either her ovipositor or her hind tarsi, depending on species, to do this. The act appears to be instinctive maternal care that provides some protection for the eggs from predation by birds, rodents, and insects. In certain species, as soon as the female retracts her ovipositor, the attendant male mates with her; females and attending males of other species merely walk away from each other.

Grasshoppers have different ways of avoiding excessively high temperatures that may occur in summer for a few hours each day. When ground temperatures rise above 120½F, individuals of certain species climb plants, some to a height of only 2 inches on grass stems, others climb higher (5-12 inches), and some even higher on tall vegetation such as sunflower in the southern mixedgrass prairie or a tall cactus plant in the desert prairie. In these positions individuals usually rest vertically with the head up on the shady side of the plant. Many ground-dwelling species first raise up on their legs or stilt, but as temperatures rise further, they crawl into the shade of vegetation. Individuals of other ground-dwelling species may stilt, then move away from the hot bare ground and climb on top of a short grass such as blue grama. They face the sun directly so that the least body surface is exposed to the radiant rays. In this orientation the grasshoppers are 1 to 2 inches above ground and rays of the sun strike only the front of the head.

Characteristic behavioral responses regularly observed by grasshopper scouts and collectors of insects are the jumping and flying of grasshoppers, apparently to escape capture. The stimuli initiating these responses may be of many kinds but circumstantial observation indicates that movement of the collector's image across the compound eye is usually the primary stimulus. One may noisily push a stick on the ground close to an individual without eliciting a response. Also other insects, such as large darkling beetles or large grasshoppers, may crawl close and elicit no response until they touch a resting grasshopper. Phytophilous species of grasshoppers may not jump or fly to escape intruding scouts and insect collectors, but may shift their position away from the intruder to the opposite side of a stem, retreat deeper into the canopy, or drop to the ground. Collectors and scouts entering the habitat of dense populations of grasshoppers may get the impression of continuous movement by these insects, but investigation of their time budgets indicates that during most daylight hours they are largely quiescent (46 to 80% of the time). Considerably less time is devoted to feeding, locomotion, mating, and oviposition.

The adults of most species of grasshoppers possess long, functional wings that they use effectively to disperse, migrate, and evade predators. Adults regularly fly out from deteriorating habitats caused by drought or depletion of forage, but they may also leave a site for other reasons. Some individuals of a population instinctively fly and disperse while others remain in the habitat. The most notorious migrating grasshoppers are Old World locusts, *Schistocerca gregaria* and *Locusta migratoria*. Several species of North American grasshoppers are likewise notable migrators: *Camnula pellucida*, *Dissosteira longipennis*, *Melanoplus sanguinipes*,

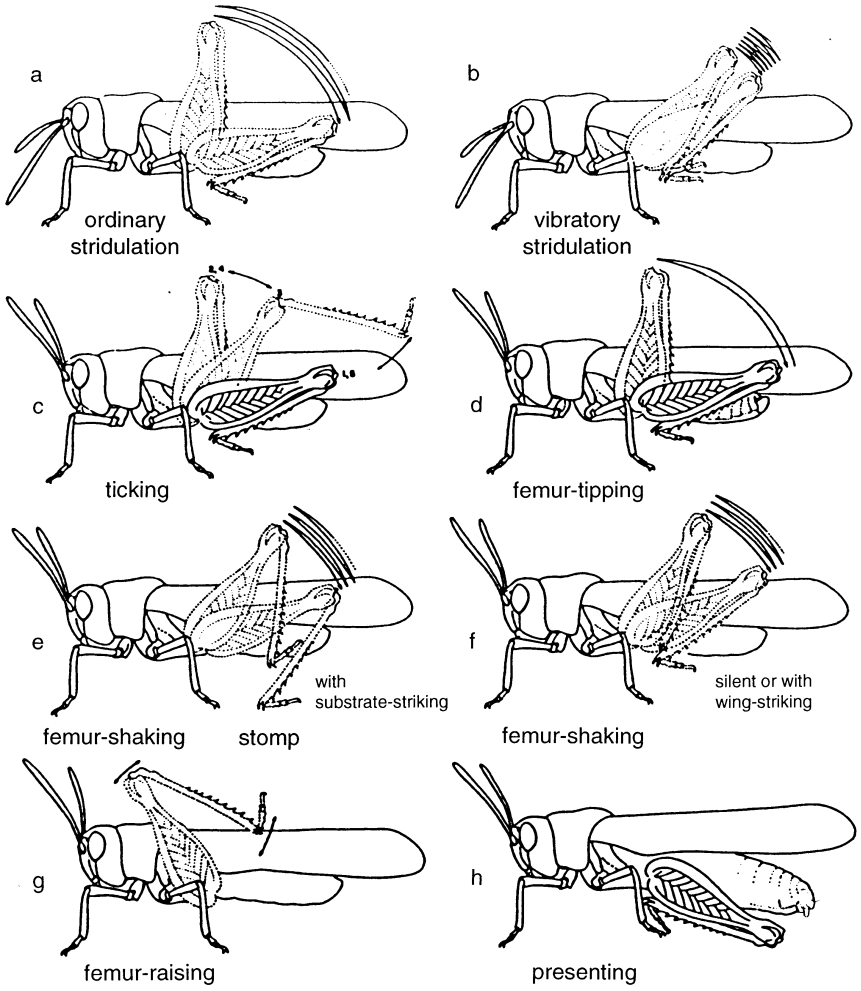

Figure 12. Signals and postures commonly occurring in grasshoppers: (a) **ordinary stridulation** — a slow, stereotyped, repetitive or non-repetitve, high amplitude movement in which the femur rubs against the forewing; (b) **vibratory stridulation** — a fast, stereotyped, repetitive, low amplitude movement in which the femur rubs against the forewing; (c) **ticking** — a stereotyped, repetitive or non-repetitve movement in which the tibiae are kicked out and struck against the ends of the forewings; (d) **femur-tipping** — a silent, stereotyped, non-repetitve raising and lowering of the femora; (e) **Femur-shaking** (with substrate-striking) — a stereotyped, repetitive shaking of the femora in which ends of the tibiae strike the substrate to produce substrate vibration or a drumming sound; (f) **femur-shaking** (silent or with wing-striking) — similar to (e) but the movement is silent, or the femora strike the forewings; (g) **femur-raising** — a slow, graded non-repetitive movement that may or may not be accompanied by mild upward kicking motions of the tibiae; (h) **presenting** — a variable, graded posturing of the female in response to male courtship, in which the end of the abdomen is made more accessible to the male by lowering both the end of the abdomen and the hindlegs. (Courtesy of Otte, 1970, Misc. Publ. Mus. Zool., Univ. Michigan, No. 141.)

M. devastator, *M. rugglesi*, *Oedaleonotus enigma*, and *Trimerotropis pallidipennis*.

Past direct observations of grasshoppers in their natural habitat have revealed various behavioral responses among species. Each appears to have its own way of reacting to a battery of environmental factors. Because a relatively few species have been investigated, much remains to be discovered. The whole subject of grasshopper behavior provides a fertile area for research both in the field and in the laboratory. Acquiring sufficient information on the various aspects of grasshopper behavior will not only serve to improve integrated management of pest species and the protection of beneficial ones, but will also advance the science of animal behavior.

Numerous observations of the behavior of common western grasshoppers have been made during the course of this study. Results of these

observations are reported later in the treatment of individual species.

Grasshopper Collections and Surveys

A well-curated collection of local grasshoppers is useful for identification and display. Insect taxonomists often identify species by comparing unknown specimens with identified museum specimens. They also make comparisons to confirm identifications that they have made from memory or by the use of a "key." These practical uses of an insect collection can also be made by plant protection personnel.

Neatly pinned and completely labeled grasshopper specimens placed in a glass-covered museum drawer make an effective educational display. Visitors —farmers, ranchers, and others — are amazed to learn that there are more than a few kinds of grasshoppers and that many kinds of grasshoppers may actually inhabit their properties. The observation of various species of grasshoppers in a collection reveals the wide diversity within this family of insects.

An interesting and useful grasshopper collection can be made with little effort and at modest expense. Anyone can capture a variety of grasshoppers within the confines of a single county by hunting for them in different habitats and at different times from spring until fall. The equipment needed to capture, preserve, label, and store grasshopper specimens consists of several simple items: (l) insect net, (2) killing jar, (3) insect pins, (4) spreading board, (5) insect boxes or museum drawers, (6) insect trays, (7) pinning block, and (8) label-making materials (paper, crow quill or rapidograph pen, India ink, and scissors).

The standard insect net (15-inch diameter) fitted with a nylon netting bag is suitable for catching grasshoppers (Fig 13). A short handle (2 feet) makes the insect net convenient for sweeping in a semicircle close to the ground as one walks at a moderate speed over rangeland or in a disturbed area. This procedure is good for capturing nymphs and slower flying adults. Adults of certain species, however, are wary and easily frightened and may fly away. An adult of such a species must be captured by visually following its flight, watching where it lands, approaching it stealthily, and then slapping the net over it. It will usually jump or fly up into the net. Then it may be extracted by hand.

A second method of sweeping for grasshoppers, with the objective of obtaining a sample of all species inhabiting a site, is to take a set of 10 sweeps close to the ground while walking slowly and then a set near the tops of vegetation at a fast walk. Repeat this procedure as necessary to obtain adequate numbers of specimens from the site. A desirable number of specimens from a site ranges from 100 to 150.

For good museum specimens, fill up the net sparsely with grasshoppers, taking a few sweeps at a time (i.e., 10-25 sweeps). For other purposes, however, such as determining relative density by the sweeping method, as many as 100 sweeps may be taken at one time.

Make collections of grasshoppers from one habitat at a time and keep specimens from a single habitat separate from specimens taken in other habi-

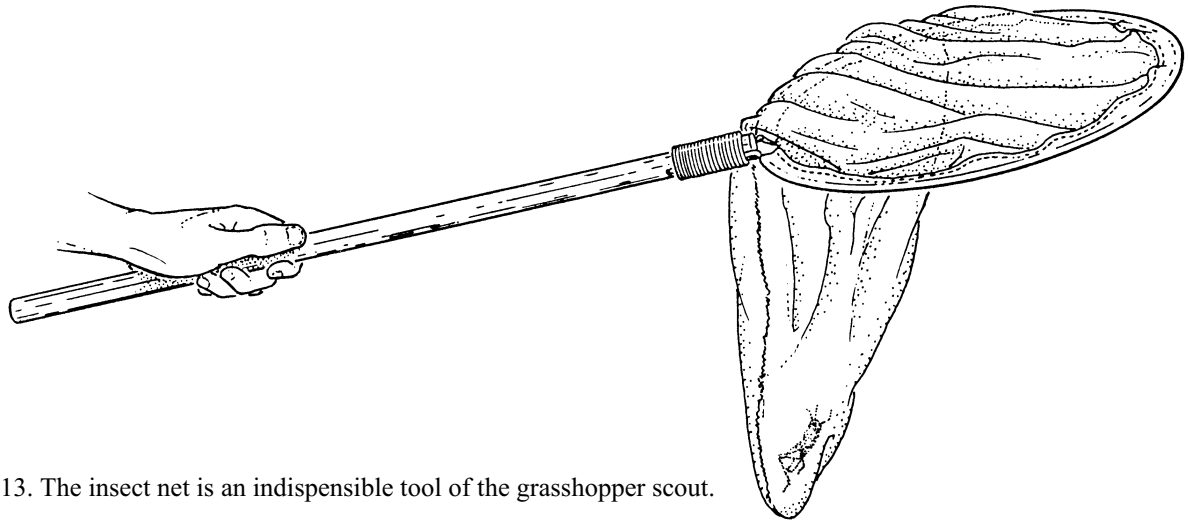

Figure 13. The insect net is an indispensible tool of the grasshopper scout.

tats. This procedure makes possible brief label descriptions indicating the specimen's habitat.

Scouts need to obtain absolute density of grasshoppers (number per square yard) at each surveyed site as well as to collect specimens for determination of species composition. The method consists of counting the number of grasshoppers in a series of 1 square foot areas. Scouts visualize a sample area approximately 15 to 20 feet ahead and on their approach carefully count the number jumping or flying out. When they arrive at the selected square foot area, they run their hands through the vegetation to flush and count any remaining grasshoppers. By walking out at least 50 feet from the road and making the counts in a wide circle, the scouts ensure that samples are taken in typical rangeland habitat. Eighteen 1-square-foot samples are taken and recorded. Scouts add the numbers counted in each square, then divide the total by two to obtain the absolute density in number of grasshoppers per square yard. Detailed instructions for grasshopper survey and recording are provided by the APHIS office in each western state.

There are several ways to kill captured grasshoppers. Killing jars can be made from wide-mouthed pint or quart jars (Fig. 14). To make an ethyl acetate jar, pour about 1 inch of plaster of paris mixed with water into the bottom of the jar and allow the plaster to dry with the lid off. Then add enough of the ethyl acetate to saturate the plaster, pouring off any excess. Whenever the ethyl acetate becomes spent or weak, recharge the jar with more. Another kind of killing jar contains potassium cyanide as the toxic agent. To make this type, pour one-half inch of potassium cyanide crystals into the bottom of the jar. Cover the crystals with one-fourth inch sawdust and then one-fourth inch thick paste of plaster of paris. Add crumpled absorbent paper to prevent condensation of water on the jar's inside surface. When ready to use, put several drops of water on the plaster. In one hour enough hydrocyanic fumes will be generated inside the jar to kill any grasshoppers placed there. To retain color of specimens, do not leave them in a killing jar much longer than it takes to kill them. For prevention of breakage and for safety, wrap the lower half and bottom of killing jars with electrical or packing tape and attach a conspicuous POISON label (Fig. 14C). Biological and entomological supply houses have improved killing jars over the homemade ones described in this bulletin. These can be purchased at reasonable prices and come with directions for charging them with recommended killing agents.

A third effective way to kill grasshoppers is to dunk them into ethyl or isopropyl alcohol for two to three minutes while they are still confined in the net. Drain and transfer them to a clean jar with absorbent paper and place the specimens in the jar in a cooler until you return to headquarters. You may then transfer specimens killed by any of the suggested

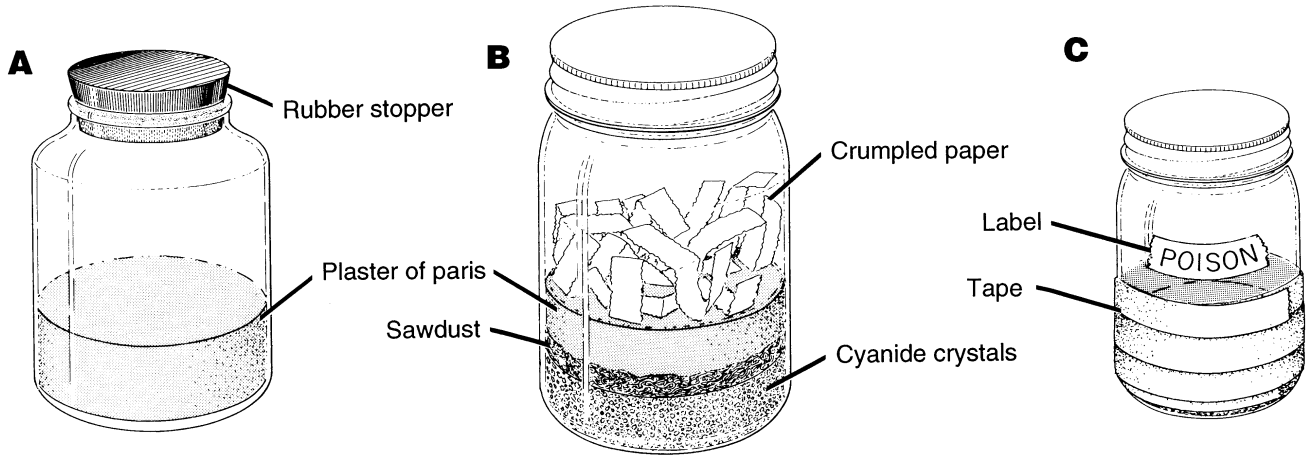

Figure 14. Types of killing jars. A, ethyl acetate saturated in plaster of paris; B, potassium cyanide crystals in bottom of jar; C, complete jar with protecting electrical tape and poison label.

methods to a refrigerator or to a deep freeze to store for periods of more than three days.

After each collection separate all of the grasshoppers from plant material such as grass seeds and pollen, which get into the net as one sweeps the vegetation. Place the grasshoppers in a heavy duty ziploc freezer bag (such as one 5x7 inches, 2.7 mils thick), gently roll the bag of grasshoppers and place it in another bag with a complete label (location, date, collector's name, etc.). Placing the label in the second bag prevents grasshopper exudates from staining it and making it illegible. Put the double-bagged grasshoppers in a cooler charged with ice or a container of frozen blue ice. To prevent soaking of the bagged grasshoppers from melting ice water, set them in a plastic container resting on the ice. At the end of the day, place the collections into a deep freeze until they can be transported to headquarters. To prevent thawing of grasshoppers when they are transported, place them in a plastic container with a tight lid in the center of an ice-filled cooler and add salt. This procedure will usually keep the grasshoppers frozen for a day or longer. These precautions are designed to retain specimens in the best condition possible for accurate identification at a later time.

The correct pinning of a grasshopper is essential in preparing a good museum specimen (Fig. 15). Use a No. 3 or 4 insect pin and for a very large grasshopper, use a No. 7 insect pin. An ordinary straight pin will not do, as it is too short and thick and prone to rust. Holding the grasshopper in one hand and the pin in the other, pierce the top of the pronotum on the right side and near the rear edge. Leave one-half inch of the pin above the specimen for safe handling of the specimen later when it has dried. As you push the pin through, keep the grasshopper oriented so it is level and not tilted on the pin in any direction. If you have erred, the pin can be withdrawn and run through again starting in the hole already made. Because the hindwings of bandwinged grasshoppers possess taxonomic characters, spread the left forewing and hindwing by mounting a few males and females on a spreading board (Fig. 16). Leave the specimens on the spreading board for a few weeks while they dry.

Pin the larger nymphs on No. 1 size insect pins but glue smaller nymphs to paper points (Fig. 17). With a hand punch, make the paper points from unlined index cards. Place a small amount of a Duco-type cement on the pointed end and mount the specimen on top of the cement. To ensure retention of color of pinned grasshoppers, place them in a deep freeze for several months to dry. Nymphs particularly require this freeze-dry method. Adults can be exposed to the air of a room in an open box to dry. During a wet season or in a humid climate, one should place mounted specimens in a Schmitt box (Fig. 18) with desiccating granules (6-12 mesh) of silica gel. Under any condition of humidity the practice will serve to retain life colors of the grasshoppers. This method requires the box with specimens and granules to be closed.

Once specimens are dry they are fully preserved, but need protection from ants and from larvae of dermestid beetles that feed on them. Place balls or flakes of paradichlorobenzene (PDB) or naphthalene in a small cloth bag and pin firmly in the corner of the insect box or drawer. A more effective insecticide is dichlorvos. Cut three-fourths inch squares from No-Pest Strip insecticide. Pin one square per box or drawer of specimens. A square will protect for as long as a year before it must be replaced.

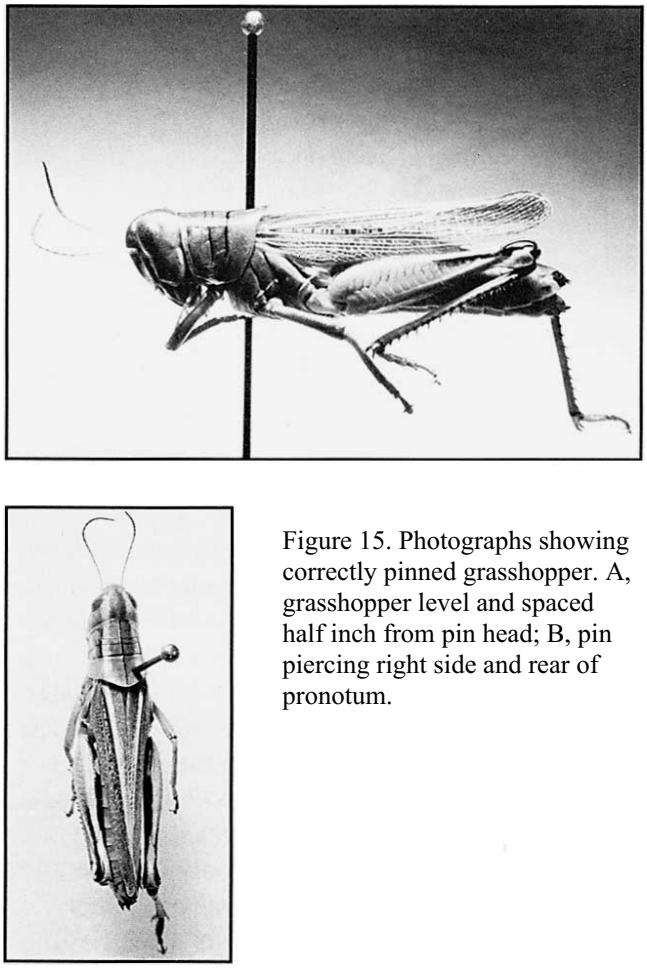

Figure 15. Photographs showing correctly pinned grasshopper. A, grasshopper level and spaced half inch from pin head; B, pin piercing right side and rear of pronotum.

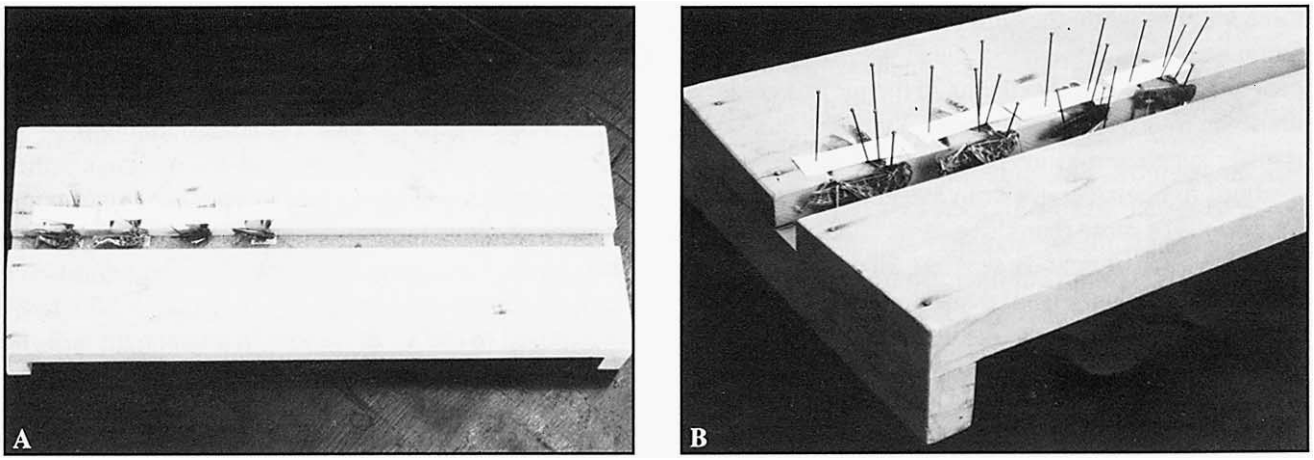

Figure 16. Grasshoppers drying with left wigs spread. left, view of whole spreading board, 19 x 7.5 inches; right, closeup of drying grasshoppers on spreading board.

Many priceless collections made in the 1800s and more recently have been destroyed by dermestids.

Large grasshoppers such as the differential and the lubber do not dry fast enough to make good museum specimens. They decay and discolor. They must be eviscerated before pinning by making a one-half inch cut lengthwise in the bottom of the abdomen (center of first three sterna) with a pair of small scissors. With a fine pair of forceps reach into the inside and extract the entrails. Replace entrails with a small cotton wad and bring cut sides of integument together. The operation will allow a large grasshopper to dry quickly. One may further ensure good preservation by placing specimens in a Schmitt box with a desiccant.

Safe storage of grasshopper specimens requires nearly airtight insect boxes or museum drawers. These are manufactured in standard sizes with hard bottoms or polyethylene foam pinning bottoms. Dimensions of insect boxes measure 9 x 13 x 2 1/2 inches (Fig. 18) and Cornell drawers 19 x 16 1/2 x 3 inches (Fig. 19). It is convenient to use insect pinning trays in museum drawers (a necessity in drawers with hard bottoms) so that specimens can be shifted around. Trays come commonly in three sizes: large 4 3/8 x 7 1/4 x 1 5/8 inches, medium 4 3/8 x 3 5/8 x 1 5/8 inches, and small 4 3/8 x 1 13/16 x 1 5/8 inches. Large and medium sizes are usually used for grasshoppers, but small trays can also be helpful on occasion.

For a museum specimen to have value it must bear fully descriptive labels, either two or three depending on division of information. In the two-label system, the top label gives the state and county in the first line, the latitude and longitude of the collecting site in the second line, the date of collection in the third line, the habitat in the fourth line, and the collector's name in the fifth line. For

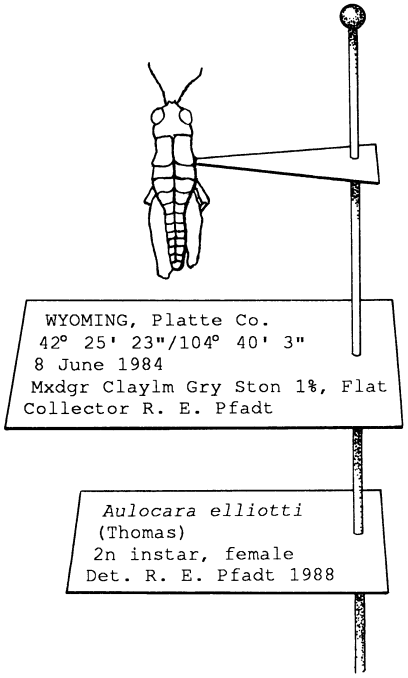

Figure 17. Nymphal grasshopper glued to card point and fully labeled. Dimensions of reduced top label on actual specimen 1 x 3/8 inch, reduced bottom label 7/8 x 2/8 inch. Note content and style of labels.

collectors who do not have available a global positioning apparatus, an equally good way to specify the location of the collection site is to use a county map from which the township, range, and section may be obtained. The second line of the top label in Fig. 17 would then read T28N R65W Sec 4 SE. Do not abbreviate the year, list fully (e.g. 1994). Your specimen may rest safely for centuries in a museum collection. Provide a short description of the habitat such as the examples shown in Table 6. In specifying the habitat, a general classification of the grasslands of the West is helpful (Fig. 21).

Whenever possible one should also indicate soil texture (sandy, loamy, clayey), color, stoniness (gravel) and rockiness (rock outcrop), and slope or relief (hillside, hilltop, flat, swale). For a detailed treatment of soil classification consult the Soil Survey Manual USDA Handbook 18 (1951). The majority of counties in the United States have published soil classifications that may be obtained from the Soil Conservation Service located in each county seat. One may then enter the soil name on the label. The bottom label gives the scientific name of the specimen, the author, the name of the person who made the identification, and the year in which the identification was made. In the three-label system, the collector's name is placed on a separate label and is positioned in the middle between the top and bottom labels. See Figure 17 for the recommended style. Use quality, heavyweight paper for labels (white paper with high rag content). Print labels with a crow quill or rapidograph pen using black India ink. If a typewriter and copy machine are available, one may type the data and reduce the information to small but legible labels. Or if a computer and laser printer are available, one may type the label and have the printer reduce it to the desired size. For a large series of specimens, printed labels may be ordered from a commercial company. Do not make labels too large. A maximum size of 1 x 3/8 inch is recommended. It is preferable, however, to exceed this when pertinent data need to be given. The labels of a specimen may differ in size so that only the size needed for the information is required of each label. Use a pinning block (Fig. 20) to make label levels uniform on all pinned specimens.

A word of caution here. Collectors often become enthusiastic about capturing grasshoppers and leave themselves insufficient time to curate what they have caught. Leave yourself enough time to pin, spread, and eviscerate specimens. Label at least one of the group with all information available. Later, label all specimens. More detailed instructions on techniques for collecting, pinning, preserving, and also shipping to specialists are provided in USDA ARS Miscellaneous Publication Number 1443 (1986).

Figure 18. The schmitt type insect box. It has a polyethylene foam pinning bottom and is nearly airtight with lid closed.

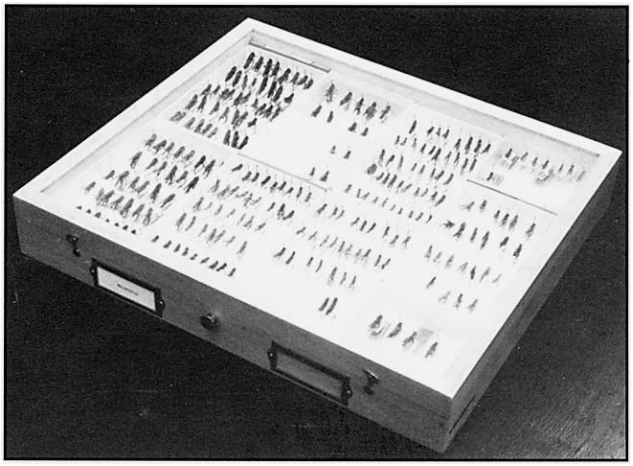

Figure 19. The Cornell type insect drawer. It has a glass cover and contains three sizes of insect pinning trays for ease of handling groups of grasshopper species.

Live grasshoppers are frequently requested by researchers. These can be mailed in a variety of containers. An easy and practical way is to obtain squat paper or plastic pint containers (like the

TABLE 6. Examples of short descriptions of grasshopper habitats. Abbreviate one of A, B, C, and D on label*.

A. VEGETATION
- Annual grassland
- Bunchgrass prairie
- Desert grassland
- Mixedgrass prairie
- Shortgrass prairie
- Tallgrass prairie
- Desert shrubs
- Mountain meadow (below timberline)
- Alpine meadow (above timberline)
- Crop (name crop) dry or irrigated
- Crop border (name crop)
- Improved pasture (name forages)
- Reversion (name plants)
- Roadside (weeds or grass or mixed)

B. SOIL TEXTURE AND COLOR

Clay	Gray
Clay loam	Yellow
Loam	Brown
Silt loam	Red
Sandy loam	Black
Sand	

C. SOIL SURFACE
- Stony %
- Rocky % (outcrops)

D. SLOPE
- Swale
- Flat
- Rolling
- North slope
- South slope, etc.
- Hilltop

** See top label of Fig. 17 for suggested style. For more precise descriptions of vegation types and soil classifications, consult with local botanists and soil scientists.*

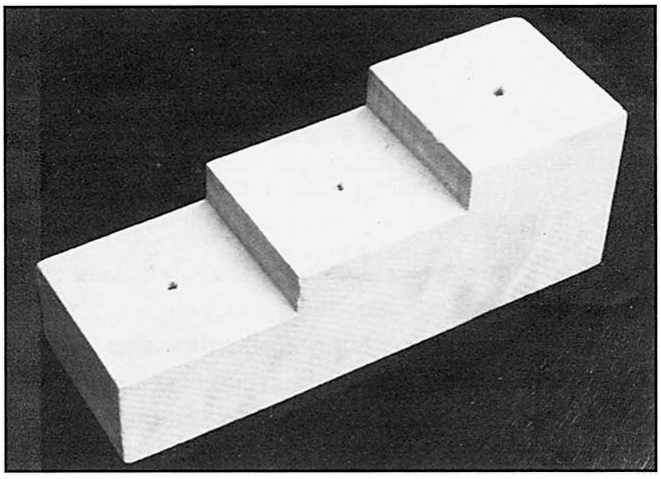

Figure 20. Insect pinning block used to make level of label uniform in the three label system.

containers for cottage cheese). These may be purchased from a market or department store. Depending on size of the grasshoppers, from 10 to 25 individuals may be caged in a pint container along with a small amount of plant food such as lettuce. Do not overload the container with green food and do not place dry cereals in the container. Punch small holes in the lid and secure with tape. Untaped lids may come off in transit, allowing grasshoppers to escape into the packing material with fatal results. Place the containers in a cardboard shipping box surrounded by packing material and ship by US Express Mail, Federal Express, or overnight United Parcel Service.

Grasslands of North America

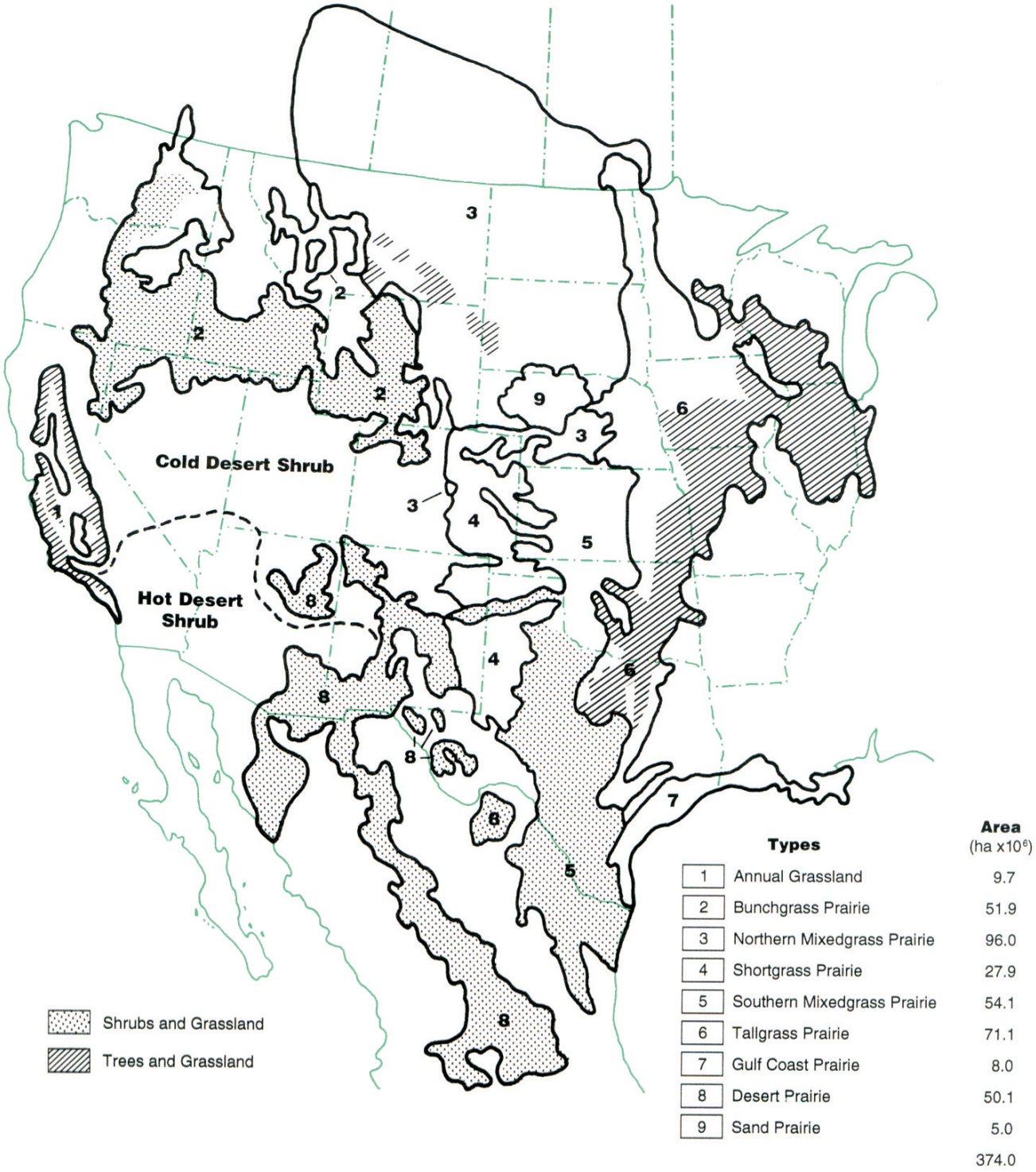

Figure 20. Map shows location of the three kinds of grasslands in North America and the cold and hot deserts dominated by shrubs but also containing sparse grasses (adapted from a map of Grasslands of North America by Dodd, 1982).

Appendix of Common-Scientific Names of Grasshopper Food Plants

Grasses

barley — *Hordeum vulgare*
barnyardgrass — *Echinochloa crusgalli*
basin wildrye — *Elymus cinereus*
big bluestem — *Andropogon gerardii*
bluebunch wheatgrass — *Pseudoroegneria* (*Agropyron*) *spicata*
blue grama — *Bouteloua gracilis*
buffalograss — *Buchloe dactyloides*
burrograss — *Scleropogon brevifolius*
crested wheatgrass — *Agropyron cristatum*
curly mesquite — *Hilaria belangeri*
downy brome — *Bromus tectorum*
fall witchgrass — *Leptoloma cognatum*
foxtail barley — *Hordeum jubatum*
foxtail brome — *Bromus rubens*
giant wildrye — *Elymus condensatus*
green bristlegrass — *Setaria viridis*
green needlegrass — *Stipa viridula*
hairy grama — *Bouteloua hirsuta*
hare barley — *Hordeum leporinum*
Idaho fescue — *Festuca idahoensis*
intermediate wheatgrass — *Elytrigia* (*Agropyron*) *intermedia*
Japanese brome — *Bromus japonicus*
Johnsongrass — *Sorghum halepense*
Kentucky bluegrass — *Poa pratensis*
little barley — *Hordeum pusillum*
little bluestem — *Schizachyrium scoparium*
needleandthread — *Stipa comata*
oats — *Avena sativa*
orchardgrass — *Dactylis glomerata*
Parry oatgrass — *Danthonia parryi*
plains lovegrass — *Eragrostis intermedia*
poverty oatgrass — *Danthonia spicata*
prairie cordgrass — *Spartina pectinata*
prairie dropseed — *Sporobolus heterolepis*
prairie junegrass — *Koeleria cristata*
prairie sandreed — *Calamovilfa longifolia*
quackgrass — *Elytrigia* (*Agropyron*) *repens*
red fescue — *Festuca rubra*
red sprangletop — *Leptochloa filiformis*
red threeawn — *Aristida longiseta*
reed canarygrass — *Phalaris arundinacea*
Sandberg bluegrass — *Poa secunda*
sand bluestem — *Andropogon hallii*
sand dropseed — *Sporobolus cryptandrus*
Scribner panicum — *Panicum scriberianum*
sideoats grama — *Bouteloua curtipendula*
silver beardgrass — *Bothriochloa saccharoides*
sixweeks fescue — *Vulpia octoflora*
slender hairgrass — *Deschampsia elongata*
slender wheatgrass — *Elymus* (*Agropyron*) *trachycaulum*
smooth brome — *Bromus inermis*
soft brome — *Bromus mollis*
spikefescue — *Leucopoa kingii*
squirreltail — *Sitanion hystrix*
stinkgrass — *Eragrostis cilianensis*
subalpine needlegrass — *Stipa nelsonii*
switchgrass — *Panicum virgatum*
tall dropseed — *Sporobolus asper*
thickspike wheatgrass — *Elymus* (*Agropyron*) *casystachyum*
timothy — *Phleum pratense*
western needlegrass — *Stipa occidentalis*
western wheatgrass — *Pascopyrum* (*Agropyron*) *smithii*
wheat — *Triticum aestivum*
wild oat — *Avena fatua*
witchgrass — *Panicum capillare*
wolftail — *Lycurus phleoides*
yellow indiangrass — *Sorghastrum nutans*

Sedges-Rushes

Baltic rush — *Juncus balticus*
elk sedge — *Carex geyeri*
needleleaf sedge — *Carex eleocharis*
Penn sedge — *Carex pennsylvanica*
rock sedge — *Carex rupestris*
sun sedge — *Carex heliophila*
threadleaf sedge — *Carex filifolia*

Forbs and Shrubs

alfalfa — *Medicago sativa*
annual sowthistle — *Sonchus oleraceus*
antelope bitterbrush — *Purshia tridentata*
antelopehorns milkweed — *Asclepias asperula*

Arizona popcornflower — *Plagiobothrys arizonicus*
aromatic aster — *Aster oblongifolius*
arrowleaf balsamroot — *Balsamorhiza sagittata*
arrowleaf butterbur — *Petasites sagittatus*
ball mustard — *Neslia paniculata*
balsamroot — *Balsamorhiza* spp.
big sagebrush — *Artemisia tridentata*
birdsfoot trefoil — *Lotus corniculatus*
bitterroot — *Lewisia rediviva*
black sagebrush — *Artemisia nova*
blood ragweed — *Ambrosia trifida* var. *texana*
bracted spiderwort — *Tradescantia bracteata*
branchy goldfields — *Baeria chrysostoma*
breadroot scurfpea — *Psoralea esculenta*
broadleaf plantain — *Plantago major*
broom snakeweed — *Gutierrezia sarothrae*
budsage — *Artemisia spinescens*
burroweed — *Haplopappus tenuisectus*
bushy wallflower — *Erysimum repandum*
Canada goldenrod — *Solidago canadensis*
Canada thistle — *Cirsium arvense*
chicory — *Cichorium intybus*
clover — *Trifolium* spp.
common groundsel — *Senecio vulgaris*
common lambsquarters — *Chenopodium album*
common purslane — *Portulaca oleracea*
common sunflower — *Helianthus annuus*
common yarrow — *Achillea millefolium*
crested pricklepoppy — *Argemone platyceras*
cudweed sagewort — *Artemisia ludoviciana*
dandelion — *Taraxacum officinale*
dogweed — *Dyssodia* spp.
Douglas rabbitbrush — *Chrysothamnus viscidiflorus*
draba mustard — *Draba* spp.
emory globemallow — *Sphaeralcea emoryi*
European sticktight — *Lappula echinata*
false boneset — *Kuhnia eupatorioides*
false dandelion — *Agoseris glauca*
Fendler sandwort — *Arenaria fendleri*
Fendler springparsley — *Cymopterus fendleri*
field bindweed — *Convolvulus arvensis*
filaree — *Erodium* spp.
fireweed fiddleneck — *Amsinckia intermedia*
flax — *Linum* spp.
flixweed — *Descurainia sophia*
foothill trefoil — *Lotus humistratus*
fringed sagebrush — *Artemisia frigida*
giant ragweed — *Ambrosia trifida*
gilia — *Gilia* spp.
globemallow — *Sphaeralcea* spp.
gray rabbitbrush — *Chrysothamnus nauseosus*
greenflower pepperweed — *Lepidium densiflorum*
gromwell — *Lithospermum ruderale*
groundplum milkvetch — *Astragalus crassicarpus*
groundsel — *Senecio stygius*
hairyleaved aster — *Aster hirtifolius*
hayfield tarweed — *Hemizonia congesta*
heath aster — *Aster ericoides*
hoary puccoon — *Lithospermum canescens*
hoary vervain — *Verbena stricta*
Hooker balsamroot — *Balsamorhiza hookeri*
horseweed — *Conyza canadensis*
kochia — *Kochia scoparia*
larkspur — *Delphinium* spp.
leadplant — *Amorpha canescens*
lemon scurfpea — *Psoralea lanceolata*
lespedeza — *Lespedeza* spp.
littleleaf horsebrush — *Tetradymia glabrata*
little mallow — *Malva parviflora*
lotus milkvetch — *Astragalus lotiflorus*
lupine — *Lupinus* spp.
meadow salsify — *Tragopogon pratensis*
milkvetch — *Astragalus* spp.
Missouri goldenrod — *Solidago missouriensis*
Missouri milkvetch — *Astragalus missouriensis*
narrowleaf bluet — *Hedyotis nigricans*
narrowleaf gromwell — *Lithospermum incisum*
narrowleaved collomia — *Collomia linearis*
narrowleaved microseris — *Microseris linearifolia*
netseed lambsquarters — *Chenopodium berlandieri*
Newmexico groundsel — *Senecio neomexicanus*
peavine — *Lathyrus* spp.
penstemon — *Penstemon* spp.
peppermint — *Mentha piperita*
pepperweed — *Lepidium* spp.
perennial sowthistle — *Sonchus arvensis*
plains bahia — *Picradeniopsis oppositifolia*
prairie onion — *Allium textile*
prairie spiderwort — *Tradescantia occidentalis*
prairie sunflower — *Helianthus petiolaris*
prairie wild rose — *Rosa arkansana*
prickly lettuce — *Lactuca serriola*
prostrate knotweed — *Polygonum aviculare*
rabbitbrush — *Chrysothamnus* spp.
red clover — *Trifolium pratense*
redroot pigweed — *Amaranthus retroflexus*

redstem filaree — *Erodium cicutarium*
rubber rabbitbrush — *Chrysothamnus nauseosus*
Russianthistle — *Salsola iberica*
rusty lupine — *Lupinus pusillus*
saltbush — *Atriplex gardneri*
sand sagebrush — *Artemisia filifolia*
scarlet gaura — *Gaura coccinea*
scarlet globemallow — *Sphaeralcea coccinea*
serrated balsamroot — *Balsamorhiza serrata*
shadscale — *Atriplex confertifolia*
shortstem lupine — *Lupinus brevicaulis*
skeletonweed — *Lygodesmia juncea*
silver sagebrush — *Artemisia cana*
skunkbush sumac — *Rhus trilobata*
slenderleaved microseris — *Microseris gracilis*
slimflower scurfpea — *Psoralea tenuiflora*
slimleaf bursage — *Ambrosia confertiflora*
soybean — *Glycine max*
spiny hopsage — *Grayia spinosa*
splendid fiddleneck — *Amsinckia gloriosa*
spreading fleabane — *Erigeron divergens*
spreading wildbuckwheat — *Eriogonum effusum*
springparsley — *Cymopterus* spp.
starlily — *Leucocrinum montanum*
tall lettuce — *Lactuca canadensis*
tansy aster — *Machaeranthera tanacetifolia*
tar weed — *Hemizonia congesta*
tar weed — *Hemizonia* spp.
tarragon — *Artemesia dracunculus*
thistle — *Cirsium* spp.
threadleaf snakeweed — *Gutierrezia microcephala*
tumble mustard — *Sisymbrium altissimum*
turbinella oak — *Quercus turbinella*
turkey mullein — *Eremocarpus setigerus*
twinpod — *Physaria* spp.
type penstemon — *Penstemon hirsutus*
upright prairie coneflower — *Ratibida columnifera*
vetch — *Vicia* spp.
Virginia pepperweed — *Lepidium virginicum*
wavyleaf thistle — *Cirsium undulatum*
western ragweed — *Ambrosia psilostachya*
western sticktight — *Lappula occidentalis*
whitedaisy tidytips — *Layia glandulosa*
white sweetclover — *Melilotus alba*
wildbuckwheat — *Eriogonum* spp.
wild licorice — *Glycyrrhiza lepidota*
wild mustard — *Brassica kaber*
wild onion — *Allium* spp.
willowleaf lettuce — *Lactuca saligna*
woolly groundsel — *Senecio canus*
woolly loco — *Astragalus mollissimus*
woolly plantain — *Plantago patagonica*
yellow eveningprimrose — *Oenothera flava*
yellow sweetclover — *Melilotus officinalis*

Glossary

Abdomen. The hind region of the insect body consisting of nine apparent ringlike flexible segments in the grasshopper (Fig. 1).

Absolute Density. The number of individual grasshoppers per unit of area, as square yard, square meter, acre, or hectare.

Accidentals. Adult grasshoppers in locations where the species does not complete its life cycle.

Acrididae. A family of insects that comprise the grasshoppers with short antennae, short ovipositor, and tarsi of legs three-segmented.

Aedeagus. The intromittent or insertion organ of the male genitalia (Fig. 8).

Allotype. A paratype specimen of the opposite sex to the holotype used in making the original description of a species.

Alpine tundra. Vegetation in montane habitats above treeline. Vegetation consists of perennial forbs, grasses, sedges, and short woody shrubs.

Anal area of tegmen. Hind or posterior part of tegmen (Fig. 7).

Annulus. A colored or light circular band.

Antenna (pl., antennae). Pair of segmented appendages (feelers) located on head and sensory in function (Fig. 1).

Anterior. Pertaining to the front of the body.

Apex. The terminal or distal part of a body structure.

Appetitive flight. Local movement by flight concerned with finding food, mates, and egg laying sites.

Apterous. Without wings.

Arcuate. Arched or humped.

Arolium. A padlike structure at the end of the insect leg between the claws (Fig. 6).

Arthropoda. A group or phylum of animals that have segmented bodies, exoskeletons, and jointed legs.

Articulate. To connect by a joint.

Bandwinged grasshoppers. A subfamily of grasshoppers, the Oedipodinae, that usually have a submarginal dark band on the hindwings (Fig. 7).

Basal. At or near base of a structure.

Bilobate. Divided into two lobes.

Bioclimatic law. Hopkin's bioclimatic law states that for every rise in elevation of 400 feet, events in the life cycle are delayed four days.

Biotic potential. The inherent properties of an organism to survive, reproduce,and increase in numbers.

Blastokinesis. Active movement of the grasshopper embryo by which it passes from the ventral to the dorsal side of the egg and at the same time revolves 180 degrees on its long axis.

Blowout. An area of renewed wind erosion in a sand dune stabilized by vegetation.

Brachypterous. With short wings.

Brood. All the individuals that hatch at about one time from eggs laid by one series of parents and that normally mature at about the same time; a group of individuals of a species that have hatched into young or have become adult at approximately the same time, and live together in a defined and limited area, and they may be of different generations.

Calcar. A spinelike process of the integument connected by a joint (Fig. 6).

Carina (pl., carinae). An external ridge of the integument (Fig. 4).

Carinula (pl., carinulae). A little carina or ridge (Fig. 6).

Center of distribution. The circumscribed area of habitats in which the species is almost always present and where dense populations regularly occur.

Cercus (pl, cerci). An appendage of the tenth abdominal segment usually triangular and short in grasshoppers (Fig. 8).

Chevrons. A pattern of V-shaped markings in one direction on the medial area of the grasshopper's hind femur.

Chorionic sculpturing. A network pattern on the chorion (shell) of the insect egg.

Cladode. A flat leaflike stem.

Clavate. Clubbed, having a thickened or expanded distal end (Fig. 2).

Clypeus. The front liplike sclerite on which the labrum articulates (Fig. 3).

Complete metamorphosis. Metamorphosis through which the insect develops by four distinct stages: egg, larva, pupa, adult.

Compound eye. An eye made up of many individual eye elements each represented externally by a corneal facet.

Concave. Hollowed out like the interior of a sphere segment.

Convex. Like the outer curved surface of a sphere segment.

Costal. Referring to the anterior portion of any wing (Fig. 7).

Coxa. Basal segment of insect leg articulating leg to body (Fig 6).

Cristate. Having a prominent carina or crest.

Crown. The perennial tissue of grasses, sedges, and forbs located near the soil surface from which all roots, herbaceous stems, and leaves grow.

Curate. To mount, label, store, and protect museum specimens.

Day-degrees. The degrees each day that the average daily temperature is above a thresholdtemperature for development. For each day that a process takes to complete, these degrees are totaled to yield the day degrees required for the process such as egg incubation or nymphal development.

Deme. A local population of a species.

Density. A measure of abundance in terms of average number of individuals per square yard, square meter, acre, or hectare.

Diapause. A state of low metabolic activity mediated hormonally and associated with ceased growth, reduced activity, and increased resistance to environmental extremes.

Dipterous. Of or relating to flies of the order Diptera.

Disk of pronotum. Central upper surface of pronotum (Fig. 4).

Disk of wings. Central area of hindwings within the margins or within the submarginal band when present (Fig. 7).

Dispersal. Outward spreading of grasshoppers from their place of origin.

Dispersion. The spacing of individuals in the habitat.

Distal. That part of an appendage farthest from the body.

Distribution. The location of all habitats in which the species lives and reproduces; the area in which the species has been recorded.

Distribution center. See center of distribution.

Dominant. With reference to grasshoppers, most abundant species in an assemblage of grasshopper species.

Dorsal. Pertaining to the top surface of the body.

Dorsal bask. The behavior of a grasshopper to increase body heat by aligning its dorsum (back) perpendicular to rays of the sun.

Dorsal posture. The position of the body taken in basking by a grasshopper so that the dorsum or back is directly exposed to the sun.

Dot map. A map showing by dots the locations where individuals of a species have been found and recorded.

Eclosion. The hatching of the larva or nymph from its egg.

Egg pod. A case made of grasshopper gluelike secretions and soil particles enclosing a clutch of grasshopper eggs.

Emarginate. Notched.

Ensiform. Broad at base, narrowing to tip (Fig. 2).

Epiproct. A triangular dorsal plate of the eleventh abdominal segment overlying the anus (Fig. 8).

Epizootic. A disease contracted by a large number of animals in a population.

Erratics. Grasshoppers that have dispersed into a habitat in which they are unable to complete their life cycle and reproduce.

Family. A taxonomic category including one genus or a group of genera of common phylogenetic origin.

F_1 generation. The generation of hybrids arising from a first cross.

Fasciate. Banded.

Fastigium. The front part of the top of the head in front of the compound eyes (Fig. 3).

Femoral stripe. The dark stripe running along the dorsal medial area of the hind femur of a grasshopper.

Femur (pl., femora). A segment of the insect leg; the stout segment of the grasshopper's hindleg (Fig. 6).

Ferruginous. Resembling iron rust in color.

Filiform. Threadlike, slender and of equal diameter (Fig. 2).

Flank bask. The behavior of a grasshopper to increase body heat by presenting a side perpendicularly to rays of the sun.

Flanking posture. The position of the body taken in basking by a grasshopper so that a side is directly exposed to the sun. Concomitantly, the associated hindleg is lowered to expose fully the abdomen.

Fledge. Acquisition of the adult wings.

Forb. Broadleafed herbaceous plant (e.g., dandelion).

Foveola (pl., foveolae). A small depression in the integument.

Frons. Front of the head above the clypeus (Fig. 3).

Frontal costa. Broad vertical ridge on the front of the head (Fig. 3).

Furcula. Forked projection from posterior edge of tenth abdominal tergum and overlying supraanal plate (Fig. 8).

Fuscous. Color of dark brown approaching black.

Griseous. Light color mottled with black or brown.

Gena. The sclerite at the side of the head (Fig. 3).

Gene. A unit of heredity on a chromosome in the cell nucleus.

Gene pool. The total genes of all the individuals of a species in a population.

Genitalia. The external reproductive structures (Fig. 8).

Genus. A taxonomic category containing a group of related species.

Geographic range. The area bounded by the location of outlying populations of a species; the location of the smallest area within an imaginary boundary line that encloses all populations of a species.

Geophilous. Living on the ground.

Gomphocerinae. A subfamily of grasshoppers known commonly as slantfaced grasshoppers.

Gradual metamorphosis. Metamorphosis through which the insect develops by three distinct stages, namely egg, nymph, adult.

Hindwings. The fanshaped membranous second pair of wings of grasshoppers (Fig. 7).

Hirsute. Hairy.

Holotype. The single specimen designated as the "type" by the author of the original description at time of publication.

Hyaline. Transparent and glassy.

Imago. A name for the adult insect.

Immaculate. Without spots or marks.

Incrassate. Thickened or swollen usually near tip.

Insecta. The insects; a class in the phylum Arthropoda in which adults have three body regions, head, thorax, and abdomen; three pairs of legs; and a respiratory system of air tubes or trachea.

Instar. The immature insect between two successive molts.

Invertebrate. Animal without spinal column or backbone.

Keel. A sharp, enlarged ridge or carina.

Key. A tabular arrangement of species, genera, families, etc., according to characters that serve to identify them.

Knee. The enlarged end of the hind femur (Fig. 6).

Larva (pl., larvae). The immature insect hatched from the egg and up to the pupal stage in orders with complete metamorphosis, e.g., a caterpillar.

Lateral carinae. The carinae at the lateral edges of the pronotal disk (Fig. 4) or of the vertex of head (Fig. 3).

Lateral foveolae. A pair of small depressions on the head at the side or front of vertex (Fig. 3).

Lateral lobe. The vertical sides of the pronotum (Fig. 4).

Litter. Plant material that falls and accumulates on the soil surface.

Maculate. Spotted.

Macropterous. With well developed long wings.

Medial. Situated in or closest to the middle.

Median area of tegmen. The middle part of tegmen (Fig. 7).

Median carina. Any ridge set medianly on an insect part, such as the pronotum or head of a grasshopper (Fig. 4).

Melanistic. Blackish due to increased amounts of black pigment.

Melanoplinae. A subfamily of grasshoppers commonly known as the spurthroated grasshoppers.

Mesosternal interspace. The area between the mesosternal lobes (Fig. 5).

Mesosternal lobes. The paired separated posterior areas of the mesosternum (Fig. 5).

Mesothorax. The middle segment of the thorax (Fig. 1).

Mesosternum. The ventral plate of the mesothorax between and in front of the middle pair of legs (Fig. 5).

Metamorphosis. The change of body form through which insects pass in developing to the adult.

Metasternal interspace. The area between the metasternal lobes (Fig. 5).

Metasternal lobes. The paired separated posterior areas of the metasternum (Fig. 5).

Metathorax. The hind segment of the thorax (Fig. 1).

Metazona. The posterior part of the pronotal disk, lies behind the principal sulcus (Fig. 4).

Migration. Mass movement of grasshoppers by walking or flying.

Molt. Process of shedding outer layers of the integument.

Nodulate. A surface sculpturing of small knots or swellings.

Notum. The dorsal part or top of a thoracic segment (Fig. 1).

Nymph. An immature insect of species with gradual metamorphosis.

Occiput. Top of head behind the compound eye.

Ocellus (pl., ocelli). The single-faceted simple eye of an insect. A grasshopper has three ocelli, two lateral and one median (Fig. 3).

Outer margin of wing. The margin between apex and anal angle of the grasshopper hindwing (Fig. 7).

Oedipodinae. A subfamily of grasshoppers known commonly as bandwinged grasshoppers.

Orthoptera. An order of insects with gradual metamorphosis, chewing mouthparts, and leathery forewings. Order includes grasshoppers and crickets.

Ovipositor. In grasshoppers the paired digging and egg laying structures at the end of the female abdomen (Fig. 1).

Ovipositor valves. Three pair of digging and egg laying structures at the end of the abdomen in female grasshoppers (Fig. 1).

Pallium. The membrane stretching across the walls of the subgenital plate and covering the male genitalia (Fig 8).

Paratype. A specimen other than the holotype that was before the author at the time of preparation of the original description and was so designated by the author.

Pellucid. Transparent whether clear or colored.

Preapical. Before the apex.

Pleuron (pl., pleura). The side sclerites of the thorax.

Posterior. Pertaining to the rear of the body.

Pottering. Intermittent walking and wandering with frequent changes in direction.

Predominant. Of grasshoppers, the most abundant species in an assemblage of grasshopper species.

Preferendum. The range of temperature at which the grasshopper comes to rest.

Preoviposition period. The period between molting to the adult and the laying of the first group of eggs; in grasshoppers the period normally lasts one to two weeks.

Principal sulcus. The hind sulcus cutting the median carina of the pronotum (Fig. 4).

Pronotum. The saddle-shaped top of the first thoracic segment (Fig. 1).

Prosternal spine. A protuberant process of the prosternum located between bases of front legs (Fig. 5).

Prosternum. The lower or ventral surface of the prothorax.

Prothorax. The front segment of the thorax (Fig. 1).

Proximal. That part of an appendage closest to the body.

Prozona. The anterior part of the pronotal disk, lies in front of the principal sulcus (Fig. 4).

Pupa (pl., pupae). The stage between the larva and the adult in insects with complete metamorphosis; a nonfeeding stage in which adult structures develop and grow.

Quadrate. Resembling a square or rectangular space.

Relative density. With reference to grasshoppers, the number caught per certain number of sweeps with an insect net or caught by hand or seen in a given period of time.

Ruderal. Growing along roadsides or in disturbed or abandoned farmland.

Ruga (pl., rugae). A wrinkle.

Rugose. Wrinkled.

Sclerite. A hardened body wall plate of insects delimited by sutures or membranous areas.

Seasonal cycle. The timing of the periods of egg hatch, nymphal development, adulthood, and reproduction.

Shoulder. The lateral angles of the metazona of the pronotum (Fig. 4).

Sibilant. A hissing sound.

Slantfaced grasshoppers. A subfamily of grasshoppers, the Gomphocerinae.

Spatulate. Round and broadened apically, spoon-shaped.

Species. A kind of organism. A genetically distinctive group of natural populations that share a common gene pool and are reproductively isolated from all other such groups.

Spine. A thornlike outgrowth of the integument not separated from it by a joint (Fig. 6).

Spur. A spinelike process of the integument connected by a joint (Fig. 6).

Spurthroated grasshoppers. A subfamily of grasshoppers, the Melanoplinae, that bear a conspicuous process (spine) on the prosternum (Fig. 5).

Sternite. A subdivision of a sternum.

Sternum. The ventral part or bottom of a thoracic or abdominal segment (Fig. 5).

Stadium (pl., stadia). The time period between two successive molts of larvae or nymphs.

Stridulate. Making a creaking or grating sound by insects through rubbing two rough surfaces against each other.

Stridulatory pegs. A row of small pegs on the inner surface of the hind femur of certain grasshoppers (most slantfaced species) (Fig. 6).

Styliform. Long and slender.

Sub-. Latin prefix meaning under; almost or somewhat.

Subarcuate. A little arched or bowed.

Subdominant. The grasshopper species of lesser abundance than the dominant one in an assemblage of grasshopper species.

Subesophageal ganglion. Three fused ganglia located in head below digestive tract innervating the mouthparts.

Subgenital plate. In the male grasshopper the terminal ventral plate underlying the genitalia (Fig. 8).

Submarginal band. The dark band usually present on the hindwings of species of bandwinged grasshoppers (Fig. 7).

Subspecies. A geographically defined aggregate of local populations which differs from other such subdivisions of a species.

Sulcus (pl., sulci). A groove or furrow in the integument.

Supraanal plate. A triangular dorsal plate of the eleventh abdominal segment overlying the anus (Fig. 8).

Suture. A linelike groove in the integument.

Swale. A depression where soils are deeper and finer textured than on surrounding upland and water availability is greater.

Tarsus. The segmented foot of an insect; three segmented in the grasshopper.

Tectate. Roof-like, sloping from a peak.

Tessellate. Mosaic or checkered.

Tegmen (pl., tegmina). The leathery, narrow, nearly parallel sided forewings of grasshoppers and other Orthoptera (Fig. 7).

Tergum. The dorsal and lateral surface of an abdominal segment (Fig. 8).

Testaceous. Brownish yellow.

Thorax. The middle body region of an insect between the head and the abdomen (Fig. 1).

Threshold. The temperature or level of hormone concentration that must be reached before development or growth can begin.

Tibia (pl., tibiae). The long, slender segment of the insect leg (Fig. 6).

Tracheal system. The respiratory system of insects that consists of internal airfilled tubes.

Trapezoidal. A figure with four sides.

Trochanter. A small segment of the insect leg located between the coxa and the femur (Fig. 6).

Truncate. Cut off squarely at end.

Tympanum. The membrane covering of the auditory organ.

Type. The single specimen that bears the name of the species and from which the species was described.

Vagility. Capacity to disperse.

Valves of ovipositor. Three pair of digging and egg laying structures at the end of the abdomen in female grasshoppers (Fig. 1).

Veins. The riblike tubes that strengthen the wings of insects.

Venation. The entire system of veins of an insect wing.

Ventral. Pertaining to the undersurface of the body.

Vertex. Top of head between the compound eyes.

Wing pads. The developing wings found on nymphs.

Wings. The hindwings of Orthoptera.

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Grasshopper Fact Sheets Arranged Alphabetically

1.	*Aeoloplides turnbulli* (Thomas)	Russianthistle grasshopper
2.	*Aeropedellus clavatus* (Thomas)	clubhorned grasshopper
3.	*Ageneotettix deorum* (Scudder)	whitewhiskered grasshopper
4.	*Amphitornus coloradus* (Thomas)	striped grasshopper
5.	*Anabrus simplex* Haldeman	Mormon cricket
6.	*Arphia conspersa* Scudder	specklewinged grasshopper
7.	*Arphia pseudonietana* (Thomas)	redwinged grasshopper
8.	*Aulocara elliotti* (Thomas)	bigheaded grasshopper
9.	*Aulocara femoratum* Scudder	whitecrossed grasshopper
10.	*Boopedon nubilum* (Say)	ebony grasshopper
11.	*Brachystola magna* (Girard)	plains lubber grasshopper
12.	*Bruneria brunnea* (Thomas)	Bruner slantfaced grasshopper
13.	*Camnula pellucida* (Scudder)	clearwinged grasshopper
14.	*Chorthippus curtipennis* (Harris)	meadow grasshopper
15.	*Chortophaga viridifasciata* (DeGeer)	greenstriped grasshopper
16.	*Cordillacris crenulata* (Bruner)	crenulatewinged grasshopper
17.	*Cordillacris occipitalis* (Thomas)	spottedwinged grasshopper
18.	*Derotmema haydeni* (Thomas)	Hayden grasshopper
19.	*Dissosteira carolina* (Linnaeus)	Carolina grasshopper
20.	*Dissosteira longipennis* (Thomas)	High Plains grasshopper
21.	*Encoptolophus costalis* (Scudder)	dusky grasshopper
22.	*Eritettix simplex* (Scudder)	velvetstriped grasshopper
23.	*Hadrotettix trifasciatus* (Say)	threebanded grasshopper
24.	*Hesperotettix viridis* (Thomas)	snakeweed grasshopper
25.	*Hypochlora alba* (Dodge)	cudweed grasshopper
26.	*Melanoplus alpinus* Scudder	alpine grasshopper
27.	*Melanoplus angustipennis* (Dodge)	narrowwinged sand grasshopper
28.	*Melanoplus bivittatus* (Say)	twostriped grasshopper
29.	*Melanoplus borealis* (Fieber)	northern grasshopper
30.	*Melanoplus bowditchi* Scudder	sagebrush grasshopper
31.	*Melanoplus bruneri* Scudder	Bruner spurthroated grasshopper
32.	*Melanoplus confusus* Scudder	pasture grasshopper
33.	*Melanoplus dawsoni* (Scudder)	Dawson grasshopper
34.	*Melanoplus devastator* Scudder	devastating grasshopper
35.	*Melanoplus differentialis* (Thomas)	differential grasshopper
36.	*Melanoplus femurrubrum* (DeGeer)	redlegged grasshopper
37.	*Melanoplus foedus* Scudder	striped sand grasshopper
38.	*Melanoplus gladstoni* Scudder	Gladston grasshopper
39.	*Melanoplus infantilis* Scudder	little spurthroated grasshopper
40.	*Melanoplus keeleri* (Thomas)	Keeler grasshopper
41.	*Melanoplus kennicotti* Scudder	Kennicott grasshopper

42.	*Melanoplus lakinus* (Scudder)	Lakin grasshopper
43.	*Melanoplus occidentalis* (Thomas)	flabellate grasshopper
44.	*Melanoplus packardii* Scudder	Packard grasshopper
45.	*Melanoplus rugglesi* Gurney	Nevada sage grasshopper
46.	*Melanoplus sanguinipes* (Fabricius)	migratory grasshopper
47.	*Mermiria bivittata* (Serville)	twostriped slantfaced grasshopper
48.	*Metator pardalinus* (Saussure)	bluelegged grasshopper
49.	*Oedaleonotus enigma* (Scudder)	valley grasshopper
50.	*Opeia obscura* (Thomas)	obscure grasshopper
51.	*Orphulella speciosa* (Scudder)	slantfaced pasture grasshopper
52.	*Phlibostroma quadrimaculatum* (Thomas)	fourspotted grasshopper
53.	*Phoetaliotes nebrascensis* (Thomas)	largeheaded grasshopper
54.	*Psoloessa delicatula* (Scudder)	brownspotted grasshopper
55.	*Spharagemon collare* (Scudder)	mottled sand grasshopper
56.	*Spharagemon equale* (Say)	orangelegged grasshopper
57.	*Trachyrhachys aspera* Scudder	finned grasshopper
58.	*Trachyrhachys kiowa* (Thomas)	Kiowa grasshopper
59.	*Trimerotropis pallidipennis* (Burmeister)	pallidwinged grasshopper
60.	*Xanthippus corallipes* (Haldeman)	redshanked grasshopper

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