

* There are 9 holometabolous orders: Hymenoptera, Neuroptera, Coleoptera, Strepsiptera, Lepidoptera, Trichoptera, Mecoptera, Siphonaptera, and Diptera. These 9 orders can be segregated into 3 groups of related orders: 1) the Hymenoptera; 2) **the neuropteroid orders: Neuroptera and Coleoptera**; and 3) the panorpoid orders: the remaining 6 orders. You should note that past versions of your text had placed the Strepsiptera as being related to the Coleoptera, but this version now places it near the Diptera among the panorpoid orders.

Introduction and Classification

The Coleoptera is the largest order of insects (probably the largest order of animals). Worldwide there are more than 300,000 species described, and there are more than 30,000 known from North America alone. Some estimates state that the number of beetle species may reach more than a million. There are more than 1300 species known from North Dakota and almost 2000 species recorded from South Dakota. There are about 120 families in North America - You will have to know less than half of this total.

The order name means sheath (Coleo-) winged (-ptera), and of course refers to the hardened front pair of wings which we call elytra. The elytra is not used in flight, but rather serves to protect the delicate membranous hind pair of wings which are folded up underneath the elytra when at rest.

The earliest classification to correctly recognize the Coleoptera as an isolated and well-characterized taxon was made by Aristotle in the 4th century B.C. Even prior to Aristotle, early man had an interest in Coleoptera: the sacred scarabs of ancient Egypt. Beetles have been eaten by primitive tribes since cavemen times.

The Coleoptera have holometabolous metamorphosis (egg, larvae, pupa, and adult stages). The Coleoptera belong to the neuropteroid orders.

Characters of Coleoptera

Head:

1. The head may or may not be concealed by the pronotum when viewed from above. It is concealed in Anobiidae, Bostrichidae, Dermestidae, Lampyridae.
2. Antennae
 - The antennae are usually 11-segmented. Read about antennal types on pp. 17-19 & 370-371 (fig. 2-15 on p. 18 and figs. 26-5, 26-6 on p. 372). You should be able to recognize and name the various antennal types discussed on these pages.
 - The keys refer to **elbowed antennae** (1st segment long and following segments small and going off at angle to first) for Curculionidae, Histeridae, Lucanidae, and Scolytidae. In other families, antennae are often bent between segments 1 & 2.
 - Some families have **asymmetrical clubs** (Fig. 26-6). Often some of the Silphidae or Trogossitidae are not very lopsided. Some antennae in other families are a little asymmetrical. Note that the shape of the antennae used to be a character responsible for some of the subdivisions within the Coleoptera, for example, those families that had clavate antennae used to be put into a group called the **Clavicornia**.
 - Pubescent antennal segments - they have a matte or velvet-like look to them.
3. Eyes - Emarginate eyes - this means that the eyes have a notch or indentation.
4. Palps - there may be reference to the palps of either the maxillae (Hydrophilidae) or labiae (Fig. 2-16).
5. Mentum - this is the distal part of the labium.
6. Snout - in Curculionidae, head is more or less prolonged forward into snout; mouthparts are reduced in size and located at tip; antennae usually arise on sides. Snout may be distinct (Brentidae, most Curculionidae) or poorly developed (Anthribidae, Scolytidae). These beetles differ from most other beetles in having the **gular sutures** fused (Fig. 26-3 C). **Gula** - a sclerite on ventral side of head between labium and foramen magnum, or between the genae, Fig. 26-4, gu; the **gular sutures** are located one on each side of the gula. There is some development of snout outside this superfamily but such beetles have gular sutures separated

Thorax:

1. Pronotum margined laterally - with sharp, keel-like lateral edge versus rounded laterally.
2. Scutellum - usually triangular, sometimes rounded or heart-shaped.
3. Prothorax (ventrally):
 - a. **notopleural sutures** - separate pronotum from propleura, Fig. 26-4, npls. Pronotum inflexed, ending at npls (Adephaga & few others).
 - b. **prosternal sutures** - separate prosternum from rest of prothorax, Fig. 26-4, stns (absent in most Curculionoidea)
 - c. **prosternum lobed** - anterior margin somewhat convex, Fig. 26-8A (Elateridae).
 - d. there is often a process or lobe extending backward between front coxae; may be spinelike, Fig. 26-8A (Elateridae).
 - e. **front coxal cavities closed** - sclerites of prothorax extend around front coxae, Fig. 26-7B.
 - f. **front coxal cavities open behind** - when sclerite immediately behind front coxa is sclerite of mesothorax, Fig. 26-7A; look at from side (Cantharoidea, Meloidae, Oedemeridae, Silphidae, Staphylinidae).
4. Metathorax:
 - a. metasternum with/without transverse suture; located in front of hind coxae - Fig. 26-4, trs.
 - b. metepisternum (located more/less laterally between legs 2 & 3, Fig. 26-4, eps₃ (Cantharidae & Lampyridae).
5. Leg characters:
 - a. coxae:
 - **globose** - rounded and project only slightly.
 - **transverse** - more or less elongate laterally without projecting very much; hind coxae, Fig. 26-8; note also Hydrophilidae, Fig. 26-22B.
 - **prominent** - conical and project ventrad noticeably - families in which front coxal cavities are open behind usually have prominent front coxae (Cantharoidea, Meloidae, Oedemeridae, Silphidae, Staphylinidae).
 - **contiguous** - touching each other.
 - b. trochanter:
 - **Suborder Adephaga** (Figs. 28-4 & 28-12A) - **displaced hind trochanters** are relatively large and strongly offset toward midline; femora may appear to touch coxae.
 - the trochanters of most beetles are small are somewhat triangular
 - c. Tarsal segments - number and relative size and shape are most important. They are 3-5 in number; usually same on all tarsi, but some have 1 less on hind tarsi; a few have fewer on front tarsi.
 - **Tarsal formula** - indicates number of tarsal segments on front, middle, and hind tarsi respectively: 5-5-5 (most Coleoptera); 5-5-4 (called **heteromerous**); 4-4-4; 3-3-3. Segment 1 is nearest to tibia; penultimate segment is next to last segment; emarginate means notched or indented; lobed means a tarsal segment that is expanded laterally and prolonged distally beneath the base of another segment (p. 375, Figs. 26-10A-G).
 1. actually 3-segmented, Fig. 26-10I.
 2. apparently 3-segmented, actually 4-segmented, 3rd segment very small, Fig. 26-10E.
 3. actually 4-segmented, Fig. 26-10C. This is sometimes called tetramerous.
 4. apparently 4-segmented, actually 5-segmented, first small, Fig. 26-10D.
 5. apparently 4-segmented, actually 5-segmented, fourth segment very small, Figs. 26-10A, B, G. These last two are sometimes called **pseudotetramerous**.
 6. actually 5-segmented, Figs. 26-10F, H, J, K. This is sometimes called **pentamerous**.
 7. Generalized rule for tarsal formulae:
 - * Cucujoidea: 4-4-4, except Coccinellidae is 3-3-3
 - * Chrysomeloidea & Curculionoidea: 4-4-4
 - * Tenebrionoidea: 5-5-4
 - * Everything else: 5-5-5, except small or rare families.
 - d. **tarsal claws** - p. 376, Fig. 26-11 - simple (not figured), toothed, cleft, pectinate.
6. Elytra - thickened, leathery or horny front wings of Coleoptera.
 - a. **stria** - a groove or depressed line (Carabidae).
 - b. **pubescent** - erect or recumbent hairs or scales (Bostrichidae, Dermestidae).

Abdomen:

1. Structure of first abdominal segment serves to separate the two principal suborders of Coleoptera.
 - Adephaga - hind coxae extends backward and bisects 1st abdominal sternum so that it consists of two lateral pieces separated by hind coxae - p. 371, Fig. 26-4; p. 376, Fig. 26-12A.
 - Polyphaga - hind coxae extends backward a different distance in different groups, but 1st abdominal sternum is never completely divided, and its posterior edge extends completely across body. May be fooled by broad & flattened (transverse) hind coxae of some Hydrophilidae (Fig. 26-19B) and Scarabaeidae or by soft-bodied insects in which coxae project over abdomen (Cantharidae and Ptilodactylidae).
2. Number of visible abdominal sterna varies in different groups and is repeatedly used in keys; first segment may be very short as in Staphylinidae.
3. In a few cases (e.g. Buprestidae), the first 2 visible sterna are more or less fused together and the suture between them is much less distinct than the other abdominal sutures, Fig. 26-8B.
4. **Pygidium** - last dorsal segment of abdomen (last abdominal tergum); sometimes exposed beyond the tips of the elytra, e.g. Histeridae, Bruchidae, Scarabaeidae.

TAXONOMY

* There are four suborders of Coleoptera according to most authorities. Two of these four are more major and two are very small suborders. There is, however, some disagreement among authorities as to the proper placement of families in suborders.

Archostemata:

The name **Archostemata** means "Ancient stem," and refers to the antiquity of this group. The pronotum in the Archostemata has **notopleural sutures**, except in the family **Micromalthidae**, which some experts put in the Polyphaga. This suborder is characterized by the wing venation and that the wings are rolled in a spiral in repose. The tarsal formula is 5-5-5. There is a fossil species that has wing venation that appears to be somewhat intermediate between the remaining Coleoptera and the Megaloptera. These are usually found under bark. The males of some species are attracted to chlorine bleach (similar to their sex pheromone).

There are only 3 families in this suborder (your text only covers the 2 New World families). The **Omatidae** has only 3 Old World Genera. There is only 1 eastern North American species in the **Micromalthidae**.

The 3rd family, for which you have a handout, is the **Cupedidae**. It is also a fairly rare family, but you may run across it (there are 25 species worldwide, 5 species in the U.S.; does not occur in North Dakota). Its common name is the reticulated beetles because the elytra are somewhat reticulated. The prosternum protudes posteriorly between the front coxae similar to the click beetles. We do have some specimens in the collection and will make them available for you to look at.

Myxophaga:

The name **Myxophaga** derives as follows: myxo- means slime, and -phaga means eaters, so these are the slime eaters (feed on algae). **Notopleural sutures** are present, but the hind coxae are not fused to the abdomen. The wings are folded basally, but spiralled distally. The tarsal formula is 3-3-3. This suborder contains only 4 small families, only 2 of which occur in North America. The **Hydroscaphidae** occurs along margins of sluggish streams and springs; and the **Microsporidae** occurs in wet gravel along streams; both families apparently feed on filamentous algae.

Adephaga:

The name **Adephaga** comes from the Greek and means "gluttonous." In this suborder the **hind coxae** are fused to the abdomen and **divide the first abdominal segment**. Also, the hind trochanters are usually relatively large and **displaced** to the side (see carabid beetles). The tarsal formula is 5-5-5. The antennae are usually filiform (except for the Gyrinidae). The notopleural sutures are present, but they are not always easy to see. The wings are folded normally in repose. Larvae have 5-segmented legs with 2 claws. These beetles are fairly common. They include many aquatic families, the tiger beetles, and the ground beetles. Most species are predatory.

Polyphaga:

The name **Polyphaga** means eaters of many things. In the Polyphaga, the hind coxae are not fused to the abdomen. The first abdominal segment is not interrupted or divided. There are no notopleural sutures. The wings are folded in repose. The tarsal formulae and antennae vary greatly. The larvae have 4-segmented legs with 1 claw. The majority (~ 90%) of species of beetles belong in the Polyphaga.

Within the Polyphaga we will recognize a number of superfamilies. The classification of these superfamilies are based primarily on wing venation, genitalia, larval characters, fossils, internal morphology, and antennal characters.

We are now ready to start going through the families of Coleoptera. We will start with the Adephaga:

Family Carabidae (ground beetles and tiger beetles)

The common name ground beetles refers to the fact that many species are usually found on the ground. The common name tiger beetles refers to their predatory habits. There are about 20,000 species of carabids, 2600 in North America. It is one of the larger families of beetles (3rd largest).

This family has actually grown considerably in recent times as several once independent families have been combined with the carabids. The round sand beetles (formerly the Omophronidae, and still considered a separate subfamily, the **Omophroninae**) and the tiger beetles (formerly the Cicindelidae, and still considered a separate subfamily, the **Cicindelinae**) have been added.

The most characteristic feature of this family is the **displaced trochanters**. You can separate the ground beetles from the tiger beetles by looking at the antennal insertions on the head. In the ground beetles, the clypeus does not extend laterally in front of antennal insertions, so the antennal insertions are on the sides of the head between the eye and the base of the mandibles. In the tiger beetles, the clypeus extends laterally in front of antennal insertions, so the antennae appear to be inserted on the front of the head above the mandibles. The tiger beetles are often somewhat shiny metallic in color.

Most species of carabids are predaceous, and are considered to be beneficial. There are a couple of species that are plant feeders (e.g. the seed corn beetle). Carabids do occur mainly on the ground and are most often found under stones, logs, etc. They tend to be nocturnal. They are usually very active and can run rapidly, but they rarely fly. Carabids are often used in biodiversity type studies.

Carabids are adapted for many different life styles. One genus of carabids have a very narrow thorax and are adapted for feeding on snails. Another group have the ability to spray a hot caustic solution on would-be predators (the Bombardier beetles). They mix 2 natural chemical secretions in the rectum which causes an explosive discharge. They also can aim this discharge to hit certain targets. Species in the genus *Calosoma* have been introduced for biocontrol projects aimed at the gypsy moth larvae. These are larger and are called caterpillar hunters; a related species is green in color and is called the fiery hunter. The subfamily **Omophroninae** (round sand beetles) are small round beetles found in the sandy or muddy areas along streams or rivers; these used to have family status. The tiger beetles seem to prefer sandy habitats. We collected them often in the sand hills, and around Mirror pool. They do like sunny, open areas, and are often common in sandy areas along streams, rivers, and along beaches. They are usually quite active and fast moving, making them difficult to catch at times. Some of the tropical species are arboreal.

Family Gyrinidae (whirligig beetles):

The compound eyes are divided by the edge of the head, so it appears that they have 4 compound eyes, 2 dorsal and 2 ventral. There is a species in the south where it is not completely divided, so we know that it is a derived condition from 2 compound eyes. The antennae are very short and very stout.

These beetles swim on the surface of the water, but they can dive when necessary. They are often gregarious, occurring in large groups. Their feet are well-adapted for swimming; the middle and hind legs move in synchrony (similar to the dytiscids). The adults are scavengers, chiefly on insects that fall in the water; the larvae are predaceous. There are 2 common genera in the U.S.: *Gyrinus* are small (less than 8mm), and *Dineutes* are larger (greater than 10mm).

Family Haliplidae (crawling water beetles):

These are small (2.5-4.5mm), yellowish or brownish beetles with black spots. The chief diagnostic character is that they have very large hind coxae that cover most of the abdomen on the ventral side (Fig. 26-19B). They do have a characteristic shape to them also. The body is somewhat tear-drop shaped and the head looks small in relation to the body.

They are aquatic, the adults often being found in masses of aquatic vegetation in slow moving or standing water. The adults feed on algae and other plant materials; the larvae are predaceous. They carry the oxygen they need for respiration under the coxae.

Family Dytiscidae (predaceous diving beetles):

There are about 4000 species worldwide, more than 500 in North America.

The dytiscids have long filiform antennae and short maxillary palps (contrast with hydrophilids: short antennae, long maxillary palps). Some species do have large hind coxae, and in all cases the hind coxae do divide the first abdominal segment.

They are aquatic and most species are predaceous in both the adult and larval forms; they feed on a variety of small aquatic animals, including fish. There are many large species (up to 25mm), but there are also some that are quite small (1-2mm & can go through aquatic net). The males of some species have suction cup-like structures on the front tarsi used to hold onto the elytra of the female during mating. They are very streamlined for swimming.

They resemble the Hydrophilidae, and this is the family in which you will mostly likely confuse them. The antennal and hind coxal characters should serve to distinguish the two. Also, the dytiscids hold their bubble of air (plastron) up under the elytra (on ventral surface in hydrophilids), and when they swim they move both hind legs simultaneously (alternate in hydrophilids).

The immatures have mouthparts very similar to the Neuroptera.

The next suborder is the Polyphaga:

Superfamily Hydrophiloidea: This superfamily contains 3 families (Hydrophilidae, Sphaeritidae, Histeridae), of which you will be required to recognize two. Note that your text includes the Histeridae in this superfamily, but other authorities place the Histeridae in its own superfamily, the Histeroidea. The Hydrophiloidea has the following characters: 1) the wing venation is called cantharoid, it has a reduction of cross veins from the ancestral stock and there is a loop formed by the medius and cubitus veins; 2) the antennae are short with segments forming a cupule to start a 3-5 segmented club; 3) the head usually has a Y-shaped suture on top; and 4) the maxillary palps are usually longer than the antennae. The Histeroidea is further characterized by having a compact body, usually having retractile appendages, and the antennae elbowed with an abrupt club.

Family Hydrophilidae (water scavenger beetles):

There are about 1500 species, with 284 in North America.

They are oval, convex beetles. They have short clubbed antennae which lie beneath the head. The maxillary palps are usually as long as or longer than the antennae, and often extend forward. The metasternum of many species is prolonged posteriorly as a sharp spine. The aquatic species are streamlined and well-adapted for swimming; the aquatic species look much like dytiscids, but can be separated from that family by the shorter antennae and the longer maxillary palps.

The adults are primarily scavengers, but the larvae are predaceous (all aquatic situations). Species of the subfamily Sphaeridiinae are terrestrial. It is believed that these species re-invaded terrestrial habitats from the water. Most of these are found in cattle dung.

The aquatic species have a hydrofuge of hairs to hold a bubble of air for breathing under water. The antennae help hold the bubble of air, and possibly the maxillary palps have taken over some of the function of the antennae. The hydrophilids replenish this bubble of air by sticking the head end out of the water, while the dytiscids replenish their air bubble by sticking the posterior end of their body out of the water. Hydrophilids swim by moving their hind legs alternatively (simultaneously in the dytiscids).

Family Histeridae (crown beetles, hister beetles):

These are usually broad, oval beetles, that are usually quite flat; they are relatively small (0.5-10mm). They are usually shiny black; the elytra do not usually reach the end of the body and are usually truncated posteriorly (exposing 1 or 2 abdominal segments). The antennae are elbowed (geniculate) and clubbed (capitate). The tibiae are usually dilated, the anterior ones usually toothed or spined. The tarsal formula is 5-5-5.

They are often found in or near decaying organic matter (dung, fungi, carrion), but are predaceous on insects (eg. fly maggots) and other small animals living in these materials. The flat species live under loose bark of stumps or logs. A few species are elongate and cylindrical and live in the galleries of wood boring insects. Some live with ants, and have varying degrees of adaptation to living with the ants: 1) synochetes (hostile commensalism) - these hister beetles are scavengers of predaceous ants and they are treated with hostility by the ants; 2) commensals - these hister beetles feed on surplus food supplies of the host ants without destroying the owners; 3) symphiles - these hister beetles are true guests of the ants and are treated quite friendly by the ants.

Superfamily Staphylinoidea: The families in this superfamily are characterized by their wing venation and by the form of the Malpighian tubules in the adults. There is no median-cubitus loop in the wing, and they have only 4-6 simple Malpighian tubules in the adults. Your text book includes seven families in this superfamily; we will discuss 2 families:

Family Silphidae (carrion beetles):

They are moderate to large in size; usually black or dark brown with red or yellow markings. The antennae are usually clubbed, either clavate or capitate, the last 3 segments are pubescent. The elytra are longer than the combined width of the elytra, but may or may not cover the abdomen. The tarsal formula is 5-5-5. The front coxae are conical or quadrate and project prominently.

The genus *Nicrophorus* are the burying beetles. They excavate underneath the carcass and bury it (the carrion won't dry out, and they will not have to compete with fly larvae). They then build a tunnel to the side of the carrion ball; it is here that they lay the eggs. When the eggs hatch, the adults stridulate to "call" the larvae to the carrion ball. The adults will feed on the carrion, and they also feed the larvae (parental care). The American burying beetle is now on the federal endangered list.

Family Staphylinidae (rove beetles):

This is a fairly large family with 30,000 species worldwide and nearly 3200 in the North America. This is the largest family of beetles in North America.

This family is usually easy to recognize, but difficult to define or characterize. They are usually relatively small (1-25mm); they are usually very elongate, slender beetles; and the elytra are usually very short, usually leaving at least the last 3 abdominal tergites exposed (they are usually not much longer than they are wide). The antennae are usually clavate and 11-segmented or less. Ocelli are rarely present. The tarsal formula is variable, but usually 5-5-5. The front coxae are conical, projecting ventrad noticeably. They have 6 or 7 visible abdominal sterna (first is sometimes very short) - this will help separate this family from short-winged members of the Nitidulidae which only have 5 abdominal sternites visible.

They occur in just about every type of habitat. Most species feed on fungi or pollen; some are predaceous (especially on Diptera). They typically raise the tip of their abdomen when they run. Some occur in caves, some with ants or termites. They are probably most often seen around decaying material, either dung or carrion. There are a few marine species (live near shorelines).

Family Pselaphidae (short-winged mold beetles; **Not Required**): The new version of the text includes this as a subfamily in the Staphylinidae. They are quite small (1.5mm) and look much like an ant (see fig. 28-25A). They have the shortened front wings like the staphylinids, but the prothorax is constricted. The tarsi are 3-segmented. Usually found on fungi or in leaf litter; a few are commensals in ant or termite nests.

Family Ptiliidae (feather-winged beetles; **Not Required**): They are also quite small (less than 1mm), and the wings bear a long fringe of hairs. Find in rotten wood, dung, and leaf litter where they feed primarily on fungal spores. I have collected these in Berlese samples at the Moorhead Science Center.

Family Leiodidae (round fungus beetles, mammal nest beetles, beaver beetles; **Not Required**): Nest inhabitants or ectoparasites of mammals; best known species is parasitic on beavers (used to be placed in the family Leptinidae). They look much like a flea that got flattened the wrong way.

Superfamily Scarabaeoidea: The adults usually have a 3-7-segmented antenna with the apical segments produced into a lamellate club (the asymmetrical club may include segments 4-10). Usually the segments of the club can be opened or closed. The legs are often somewhat fossorial, that is fitted with spines and adapted for digging. The tarsal formulae are usually 5-5-5 (except sometimes anterior tarsi of some scarabs). Most taxonomists are in agreement about this grouping.

Family Lucanidae (stag beetles):

About two-thirds of the species occur in the western U.S.

The antennae are flattened and the club is not capable of compacting into a ball; the antennae appear to be elbowed; the 1st segment is often relatively long. The head lacks any horns. The mentum is entire. Stag beetles are usually brown or black in color. Mandibles of the males vary allometrically; that is, small males will have mandibles similar in size and shape to the females; larger males have greatly enlarged mandibles. The males use the large mandibles for fighting and for predation. There is some speculation that they may also be for sexual attraction (analogous to antlers in mammals).

Larvae feed on juices of decaying wood. Adults possibly feed on honey dew or tree secretions. Found in forested areas, so they are scarce in the Dakotas. There are at least two and possibly three species in North Dakota. They are smaller species without greatly produced mandibles. The adults are attracted to lights.

Family Passalidae (bess or bessie beetles):

There are only 4 species in the U.S. and they are more common in the south and east.

They look like lucanids, but they have deep striae (grooves) in the elytra. They also have a horn on the top of the head; and there is usually a median groove on the pronotum. The antennae cannot be compacted into a tight ball, and they are not elbowed; the 1st segment is usually relatively short. The mentum is deeply notched. They also occur in decaying wood where they live in poorly organized colonies. The adults will feed the young with salivary secretions (regurgitations). The larvae always occur with adults; they also can make a squeaking noise (stridulate). The adults are not usually attracted to lights.

Family Trogidae (skin beetles):

This used to be included as a subfamily of the Scarabaeidae. They have a relatively distinct appearance. The elytra are somewhat roughened in appearance with irregular ridges and elevations. The 2nd antennal segment does not arise from the apex of the 1st segment, but rather just proximad of the apex (similar to anteapical claws). The abdomen has 5 or fewer visible sterna. These beetles are most commonly found on dried carcasses of dead animals; they feed on the skin & hair after most of the flesh has dried away. There are only 2 genera in the U.S. with most of the spp. in the eastern U.S. belonging to *Trox*.

Family Scarabaeidae (scarab beetles):

This is a large family with a number of subfamilies. Many of these smaller groups have their own common names.

There are over 18,000 species worldwide, and about 1400 species in North America. This is another favorite family for beetle collectors. This is probably one of the best known families for ND because 2 different graduate students have worked on it. Many of the included subfamilies have been elevated to full families. For example, the Geotrupidae has 11-segmented antennae.

The antennae are lamellate or flabellate and they end in an asymmetrical club of 3-7 segments which can flex or contract into a tight ball; it is not elbowed. The front tibiae are often modified for digging (fossorial). The size can be quite variable ranging from 1-100mm.

The larvae are white, usually C-shaped grubs with thoracic legs and the abdomen broader than the thorax (scarabaeiform).

The ecology is very diverse, and I will discuss it more as we discuss the subfamilies:

A. Subfamily Scarabaeinae (dung beetles, tumblebugs): Includes the sacred scarabs of Egypt. They make balls of dung and bury it where they lay the eggs, and then the larvae develop on the dung. These

are usually somewhat broadly rounded and robust beetles, which sometimes have horns on the head and pronotum. The 2nd antennal segment arises from the apex of the 1st. The hind legs are situated far back on the body, usually closer to the tip of the abdomen than to the middle legs. The abdominal spiracles are usually covered by the elytra, and the antennal club is usually pubescent.

- B. Subfamily Melolonthinae (June beetles, chafers): This is a large and widely distributed group. All of the members are plant feeders. Second antennal segment arises from apex of 1st segment. The hind legs are not situated way back on the body, and there is at least one spiracle exposed. The antennal club is usually smooth or at most sparsely pubescent. The tarsal claws are usually toothed or bifid. This subfamily contains the common and familiar June bugs which are known as white grubs in the larval form. Several species can cause economic damage (genus *Phyllophaga*).
- C. Subfamily Dynastinae (Rhinceros beetles, hercules beetles, elephant beetles): This subfamily contains some of our largest species. They possess the characters of the Melolonthinae except the tarsal claws are simple. The dorsal surface of the body is rounded and convex. The males will often have horns on the head and/or thorax.
- D. Subfamily Cetoniinae (Flower beetles): They have the characters of the subfamily Dynastinae except the dorsal surface of the body is usually flattened and there is usually a shallow emargination in the elytra just behind the humeri. They feed on pollen and are most frequently collected resting in flowers. Contains the green June bug common in the southern U.S. One genus occurs in ant nests.
- E. Subfamily Rutilinae (shining leaf chafers): These are relatively common, and you may have collected specimens. Claws of both middle and hind tarsi are unequal in length. Many of the larvae feed on plant roots while the adults feed on foliage and fruit. Many adults are brightly colored. Includes the Japanese beetle, the grape pelidnota, the goldsmith beetle, and the brilliant beetles in the genus *Chrysina* (formerly *Plusiotus*).

There are several other subfamilies in the Scarabaeidae that are common enough for you to have collected some specimens. You will have to verify their identifications by running them through the key.

Superfamily Scirtoidea: Another text includes these in with the Dascilloidea. There are 5 families we will discuss one.

Family Scirtidae (marsh beetles):

They use to be called the family Helodidae (may still be labeled that way in study material). There are 37 North American species.

They are relatively small (2-4mm). In many species, the hind femora are enlarged for jumping. The tarsal formula is 5-5-5 and the abdomen has 5 visible segments. The hind coxae are excavate, that is the hind femora fit into them. The larvae are aquatic and have a mola. They occur in streams, and also sometimes in tree holes.

Note: Rhipiceridae (superfamily Dascilloidea) larvae are internal parasitoids of cicada nymphs.

Superfamily Buprestoidea: contains the single family, Buprestidae.

Family Buprestidae (metallic wood-boring beetles; larvae called flat-headed borers):

There are about 15,000 species world wide, and once again, this is a favorite family for beetle collectors because many of the species are brilliantly colored.

The head is hypognathous and sunken into the thorax. The antennae are short and serrate. The pronotum has posterior interlocking device and incomplete lateral edges. The prosternum is long in front of coxae and has a broad intercoxal process which is received into a cavity on mesosternum or also to metasternum. The metasternum usually has a transverse suture. The first 2 abdominal sterna are usually partially fused (the suture between them is less distinct than the sutures between the remaining abdominal segments). The tarsal formula is 5-5-5, and there are 5 visible abdominal sterna.

The adults are active fliers. During flight the elytra are lifted slightly but remain closed, the wings protruding below emarginations behind humeri. Some black and yellow species mimic bees and wasps in flight. They usually feed on the nectar of flowers. The larvae feed on both living and dead plant tissue (under bark, in twigs, in roots of trees and shrubs, and in stems of herbaceous plants). Some form galls, others mine leaves. An

important pest in our area is the bronze birch borer that attacks birch trees. They are widely distributed, but more common in the western U.S.

Superfamily Byrrhoidea: We will discuss 4 families (only 3 are required) in this superfamily. Most of these families are aquatic, but most of the adaptations for aquatic living are seen in the larval forms. The larvae usually have retractable tracheal gills from the rectum. The adults usually have the posterior margin of the pronotum crenulate.

Family Elmidae (riffle beetles):

There are over 85 North American species.

The antennae are usually filiform and 11-segmented (there are exceptions). The front coxae are globose; the tarsal formula is 5-5-5, with the last segment long with long claws.

The larvae and most adults are aquatic (the larvae leave the water to pupate). They occur on plants or debris (wood, roots, leaf litter, gravel, etc.) in relatively sediment free sandy or gravelly streams. They feed on algae, moss, roots, and other plant material. They are usually in the fastest moving parts of the stream (hence the name riffle beetles) where the oxygen content of the water is the highest.

Family Dryopidae (long-toed water beetles):

The head is partially withdrawn into prothorax. The antennae are very short, with the last 8 segments serrate or pectinate, often hidden. The front coxae are transverse; the tarsal formula is 5-5-5, with the last segment long with long claws. There are 5 visible abdominal sterna. They look similar to the previous family, the Elmidae, but are usually larger in size. Some species in the genus *Pelonomus* have a covering of hairs on the compound eyes.

These are unusual in that the larvae are terrestrial and the adults are aquatic. The adults are aquatic or semi-aquatic, and are sometimes attracted to lights. They cling to vegetation or debris (roots, wood, gravel) in well-aerated streams. They respire via a cuticular plastron, some can remain submerged indefinitely. Larvae live in soil or decaying wood (may be terrestrial).

Family Heteroceridae (variegated mud-loving beetles):

There are only 28 North American species and they all look very similar.

The mandibles protrude forward. Most of the species burrow in the soil and so the front and middle tibiae are dilated with an outer row of heavy spines (similar to the scarabs). The antennae are very short, the last 7 segments form an oblong serrate club. Tarsal formula is 4-4-4, segments 1 & 4 are much longer than 2 & 3.

Adults and larvae dig burrows in mud or sand along banks of ponds, streams, or lakes. Adult burrows are usually marked by chimneys; may often be forced to leave burrows by splashing water onto shore. Some adults scavenge on animal material; larvae feed on either plant or animal material. Some are attracted to lights.

Family Psephenidae (water-penny beetles; **Not Required**):

Common name comes from larval shape which is broadly rounded and oval much like a penny. This is a small family with only 6 North American species which are eastern in distribution. The larvae are more commonly encountered than the adults.

There are 6 or 7 abdominal sterna, but the first 3 abdominal sterna may be partially fused. The adults are also oval, flattened, and dark in color. The tarsal formula is 5-5-5 with long tarsal claws.

The larvae are aquatic occurring on stones in swift moving areas of the stream. They are probably phytophagous.

Superfamily Elateroidea: The antennae are usually filiform, serrate, or pectinate, rarely clubbed. Posterior angles of prothorax are usually produced and acute. The base of the prothorax has an interlocking device (not crenulate). It is usually a jumping "clicking" mechanism involving prothorax and mesothorax. Prosternal process fits into a cavity in the mesosternum. The procoxae are usually rounded; the trochanters reduced and concealed. The elytra usually has 9-10 striae. The metasternum lacks a transverse suture. The metacoxae are nearly always excavate. There are usually 5 visible abdominal sternites. The tarsal formula is 5-5-5, rarely with membranous lobes. The larvae are usually elongate, called wireworms. There are 6 or 7 families in this superfamily; you will be required to know just one of these.

There are a number of other families in this superfamily (Cebrionidae - rain beetles - they only fly in the rain, Throscidae, Eumenidae, etc.) that you may run into; be aware of them.

Family Elateridae (click beetles):

The prosternum is armed with a spine that projects into a groove on the mesosternum. The posterolateral corners of the pronotum are produced into sharp points. They are usually elongate slender insects, either rounded at both ends, or often narrowed posteriorly. The antennae are usually filiform, but sometimes serrate or pectinate; the tarsal formula is 5-5-5; and there are usually 5 visible abdominal sternites.

The adults are phytophagous, and occur on flowers, under bark, or on vegetation. The larvae are called wireworms, and many species are very destructive, feeding on newly planted seed and the roots of agricultural crops. The larvae usually live in loam, clay or sandy soils. The eyed-click beetle (eyed elator) larvae live in logs and eat larvae of other insects. In other elators (genus *Pyrophorus*) there are spots in the posterior corners of the pronotum which are luminescent or glow in the dark. It is the same light producing mechanism as seen in the Lampyridae, but they do not turn the light on and off - they can control the intensity, however, with the light becoming brighter when threatened by a predator. Many species are attracted to lights.

Superfamily Cantharoidea: There are about 10 families; we will cover 4. Your text book includes all of these families in the Elateroidea. The larvae are distinct in that they have a grooved channel in the mandible, a feature correlated with their predaceous habits. The adults usually have the antennae not clubbed, but rather usually filiform or serrate (nearly plumose in Phengodidae). The elytra usually covers the abdomen. They appear soft-bodied - the elytra are flexible. The abdomen has 7 or 8 visible sterna which are not fused. The tarsi are 5-5-5, with the 4th segment often lobed on ventral surface. The ocelli are absent.

Family Lycidae (net-winged beetles):

These are soft-bodied beetles, usually easily recognized by the ridges or reticulated sculpturing on the elytra. The elytra are widest near the posterior end. They often are dark black with yellow or orange markings.

Adults feed on juices of decaying plant material, or some do not feed at all. They usually occur in wooded areas. The larvae are predators, usually under bark (snails, small insects, earthworms). Many of the species are distasteful to predators (other families mimic the net-winged beetles: some Cerambycidae, some Ctenuchinae [Arctiidae], some Hemipterans).

Family Phengodidae (glowworms):

Most are somewhat broad and flat beetles, with the elytra short and pointed, and the abdomen covered only by the membranous, fan shaped, non-folding hind wings. The antennae are usually serrate, but in some males they may be pectinate or even plumose. The adult females are wingless and luminescent, and they look much like larvae. The larvae are predaceous.

Family Lampyridae (lightningbugs, fireflies):

The adults are somewhat flattened, elongate-oval, 5-20mm in length, and are usually brown, yellow or sometimes marked with red or darker markings. The head is usually covered by large the triangularly-oval pronotum. Antennae are 11-segmented, filiform or serrate. The elytra have the sides nearly parallel, usually with 2 ridges or carinae on each. They usually have luminescence organs on the 6th and 7th abdominal sternites. The females of some species are wingless and look like larvae. The mesal margin of the metepisternum is straight or nearly so (works for most).

The light is a cold light (no heat involved) with nearly 100% efficiency in energy conversion. The luminous organs have originated from the fat cells; these light cells have a reflective membrane behind them. They contain a substance called luciferin which is oxidized to oxyluciferin in the presence of an enzyme known as luciferase. Production of light is under complete control of the insects, which regulate the passage of air to the luminous cells via control of the trachea. They use the light for mating purposes. Codes are used to signal for males (species isolating mechanism). There are some predators (*Photuris* spp.) that will mimic the signals and feed on the males when they come in to check out the signals.

Some of the smaller species lack light organs. They are usually active in daytime.

The larvae are predaceous and feed on smaller insects, snails (mainly terrestrial), or slugs.

Family Cantharidae (soldier beetles):

There are nearly 500 North American species.

They are often relatively brightly colored, with yellows and black most common (aposematic coloration - contain antifeedant compounds in hemolymph & release defensive compounds from segmental glands - serve as models for other insects mimicing them). Body is elongate; sides are usually parallel, or they are just a little bit wider in the middle; they are somewhat flattened, 1-15mm in length. The head is oval to triangular or subquadrate, and not hidden by the pronotum. Antennae are 11-segmented, filiform, and usually inserted between the eyes. The pronotum is broader than the head. They lack light-producing organs. Mesial margin of metepisternum more or less curved posteriorly.

The adults are usually common on flowers, especially goldenrod and milkweed. The adults feed on pollen and nectar. Many of the larvae are predators on grasshopper eggs; some are predaceous on small caterpillars and snails. A few species are omnivorous and also feed on plants such as wheat, potatoes, celery, etc. They overwinter as larvae and can be seen on snow when melting water flushes them out of hinding.

Superfamily Bostrichoidea: Body heavily sclerotized and compact; the head is often deflexed and retracted into the prothorax. There are no dorsal ocelli (except the Dermestidae has 1 or 2 dorsal ocelli). The antennae are filiform, serrate, or elongate with an asymmetrical club; antennal insertions are not concealed by frons (as in Elateridae). The pronotum is usually hood-like; the front coxae are globular to conical; the elytra are entire, often striate-punctate; the tarsal formula is 5-5-5 with simple claws; the abdomen has 5 visible sternites. There are 4 families listed in your text; we will cover 3.

Family Dermestidae (dermestid beetles, skin beetles):

About 125 species in North America; about 700 species worldwide.

They are relatively small (1-12mm), ovate, strongly convex to slightly flattened, a few species are elongate and narrow. Ground color is dark, but they are often clothed with hairs, scales, or scale-like setae which often form multi-colored patterns. The head is usually not visible from above; the antennal club is usually 3-segmented (3-9 segmented in *Trogoderma*), and often fits into a groove on the underside of the head. Has 1 or 2 dorsal ocelli. The procoxae are conical and projecting, sometimes transverse. Metacoxae are often excavate (to receive hind femur).

The dermestids are mostly scavengers and feed on a great variety of plant and animal products, including leather, furs, skins, museum specimens, woolen or silk materials, rugs, stored food materials, and carrion. Most of the damage is done by the larvae which will feed on both plant and animal material, and are found in many places including nests of ants, termites, bees, wasps, mammals, and birds. The adults feed on pollen and nectar. They do have some benefit as scavengers. Common in old nests of Hymenoptera.

Some dermestids feed on carcasses of vertebrates (and are often used by zoologists to clean animal skeletons, *Dermestes*). The larder beetle eats meats and cheese. The carpet beetle will damage carpets and furniture. Another species, *Trogoderma*, is a major pest in stored grains. Several species will attack insect collections.

Family Bostrichidae (bostrichids, branch & twig borers, false powderpost beetles):

The head is not or only scarcely visible from above. They are elongate and cylindrical, pubescent or bare; the antennae are straight, 8-11 segmented, usually with a 3-segmented club. The pronotum is usually without lateral edges, is usually tuberculate, and may have a blunt horn-like process. The dorsal surface is often roughened or rugose, somewhat tuberculate (or wrinkled); the elytra often have distal spines or teeth. Tarsal formula is 5-5-5, with the 1st segment very small. Most likely to confuse these with scolytids: bostrichids have antennae with an elongate-shaped club; the scolytids have antennae with a tight ball-shaped club.

Only a few can attack seasoned wood. They can attack living trees, but also attack dead branches and twigs. One species can bore through lead cable (called the lead cable borer). The lesser grain borer is a pest of stored grains and cereals. These are sometimes collected at lights.

The subfamily Lyctinae (powderpost beetles) was treated as a separate family in previous versions of your text. They have the head prominent from above. The antennae have a 2-segmented club (New World species). Tarsal formula is 5-5-5, with the 1st segment very small. These are slender, elongate, rather flat, brown to black beetles, 2-7mm long. Pubescence very fine, rarely scale-like. The common name derived from the fact that they bore into dry or seasoned wood and reduce it to powder. They live beneath the surface of the wood for

many months, and wood from which the adults emerge may be peppered with tiny holes. *Lyctus* is a very frequent pest in wooden artifacts derived from monocotyledonous plants. Often in bamboo.

Family Anobiidae (anobiid beetles):

They are small (1-8mm). They are cylindrical to somewhat oval pubescent beetles; the head is deflexed and usually concealed by hood-like pronotum; the antennae are 9-11 segmented, filiform, serrate, either with last 3 segments longer, or sometimes pectinate or flabellate; antennal insertions are far apart, except in subfamily Ptininae (see below). The tarsal formula is 5-5-5, with segments 2-4 decreasing in length; the appendages are often retractile.

They live in logs, twigs, and plant stems, or some in fungi or seeds. Includes the drugstore beetle (drugs, extremely bitter or poisonous to humans, and cereals), the cigarette beetle (cereals, spices, pet foods, dried tobacco, insect collections), the furniture beetle, and the deathwatch beetle.

The subfamily Ptininae (spider beetles) was treated as a separate family in earlier versions of your text. These are quite small (1-5mm). They are elongate to oval; the head and pronotum are much narrower than elytra. The head is usually concealed from above. The antennae are 11-segmented, filiform, and the antennal insertions are close together. There is no lateral edge to the pronotum. The tarsal formula is 5-5-5, simple. Some of the species are spider-like in appearance, usually covered with hairs or scales. They are more abundant in the drier parts of the world. They feed on a variety of animal and plant material. Several species have been recorded from bat guano and other dung (rat); also found in nests of birds, mammals, and other insects (esp. ants). Some are found in stored foods, where they are considered to be minor pests.

Superfamily Cleroidea: Small to medium-sized, soft-bodied; tarsal formula is 5-5-5. Head usually prognathous. Antennae clubbed or filiform. Most are predatory. We will study 3 families.

Family Trogossitidae (bark-gnawing beetles):

Other names for this family are Ostomatidae or Ostomidae. 13 genera and 55 North American species.

The antennae are clavate or terminate in a 3-segmented (poorly defined) club, segments are enlarged laterally. The tarsal formula is 5-5-5, with 1st segment very short; the front coxae are transverse. There are 5 visible abdominal sterna. There are 4 subfamilies, each with differing forms. The Trogossitinae are cylindrical to flattened, with the head as wide as pronotum; pronotum separated by narrowed "waist" from elytra (some species are bright blue-green in color). The Peltinae are flattened, with head about one-half width of pronotum, no waist, elytra sculptured (resemble sap beetles).

Often found under bark, in woody fungi, or in dry vegetable matter. Trogossitinae are chiefly predaceous on insects under bark. Some can inflict painful bite. The cadelle beetle occurs commonly in granaries. The Peltinae feed chiefly on fungi.

Family Cleridae (checkered beetles):

Common name due to many species are brightly colored. They are most common in the southwestern U.S. 35 genera and 261 North American species; about 3500 species worldwide.

The head is as wide or wider than the pronotum, which is narrower than the elytra and usually is without lateral margins; the elytra is bristly. Antennae are usually clubbed, sometimes serrate, pectinate, rarely filiform. The tarsal formula is 5-5-5, with either 1st or 4th segment very small, and segments 1 or 2 to 3 or 4 lobed beneath; front coxae conical. Elongate, pubescent, often brightly colored beetles.

Majority are predaceous as both adults and larvae. Many are common on or within tree trunks and logs, where they prey on the larvae of various wood-boring insects (chiefly bark beetles). A few are scavengers. One species is occasionally destructive to stored meats or carrion (called ham beetle). Some feed on pollen. Many can be collected resting on flowers. A few live in bee nests and feed on nectar.

Family Melyridae (soft-bodied flower beetles):

Earlier texts called it Malachilidae. 47 genera and over 500 North American species, most occur in the western U.S.

They are soft-bodied, 10mm or less in length. Many are brightly colored, red, blue, and black; the body is pubescent, hairs finer and less dense than that in Cleridae. The elytra in eastern U.S. species are widest posteriorly. The head is partially covered by pronotum, which is margined laterally. In males, the 2 basal antennal segments

are usually greatly enlarged. The hind coxae are transverse; tarsal formula is 5-5-5, 4-5-5 in males (this will distinguish them from the Chrysomelidae). Peculiar orange-colored sacs along sides of body may be everted or withdrawn into body - believed to be defensive scent glands.

Adults occur on flowers and foliage; are predators on other insects. Some are pollen feeders. The larvae often occur under the bark of dead trees or in leaf litter where they are carnivores or scavengers.

Superfamily Cucujoidea: These are small beetles, usually with clubbed antennae. We will cover 6 families.

Family Nitidulidae (sap beetles):

About 3000 species worldwide; about 165 North American species.

They are small (less than 12mm), elongate-robust to broadly oval; some species resemble tortoise beetles. The antennae are 11-segmented with abrupt 3-segmented club (some species have terminal segment annulated, causing club to appear to be 4 segmented; also rarely will have 2-segmented club). The elytra are usually shortened and truncated so that there is usually 1-3 abdominal tergites visible; the elytra are non-striate. The fore-coxae are transverse; the hind coxae are grooved; the tarsal formula is 5-5-5 (rarely 4-4-4), with 4th segment small, tarsi often dilated and pubescent beneath. There are 5 visible abdominal sternites.

Most nitidulids are found where plant fluids are fermenting or souring; e.g., around decaying fruits or melons, flowing sap, and some types of fungi. A few in dried carcasses of dead animals. Several economic pests, in corn, strawberries, picnic beetles; many occur on flowers. May confuse with Staphylinidae or Histeridae, but those families have 6-7 abdominal sternites visible.

Family Silvanidae

This family used to be considered a subfamily in the Cucujidae. Your text now has it as a separate family. It is characterized by having clubbed (clavate) antennae, the antennae only reaching to about middle of pronotum.

The tarsal formula is 5-5-5 with the 4th segment small. They are somewhat flattened, 2.5-3.0mm in length.

The saw-toothed grain beetle (named for lateral teeth on pronotum) is a pest of stored grain worldwide.

Family Cucujidae (flat bark beetles):

23 genera and 88 North American species. This family has recently been split into a number of separate families (Silvanidae, Passandridae, Laemophloeidae).

They are monochromatic brown, reddish or yellow. The tarsal formula is 5-5-5, with 1st tarsal segment very small.

The antennae are relatively straight. These are extremely flattened, 1.5-14mm, antennae thread-like or beaded (filiform or moniliform) and extending to base of elytra or longer.

Many feed on mites under bark of fresh cut logs.

Family Languriidae (lizard beetles):

4 genera and 38 North American species, mostly in southern U.S.; 400 species worldwide.

They are elongate-slender beetles with nearly parallel sides, 2-10mm in length. They are usually shining, often red or orange head and pronotum, and black elytra. Antennae are 11-segmented with a 3-6 segmented club. The tarsal formula is 5-5-5, with 4th segment small, and segments 1-3 very pubescent beneath.

Larvae are stem borers on legumes and composites. Adults are pollen feeders. The clover stem borer is a minor pest of red clover and alfalfa.

Family Erotylidae (pleasing fungus beetles):

10 genera and 50 North American species, mostly in the eastern U.S.

Elongate-oval to broadly oval, 2.5-22mm. The tarsal formula is obviously 5-5-5 (Dacninae, some authors raise this group to full family status), or with 4th segment very small (in rest of family). They are shining, usually black and orange with blotches or transverse stripes, occasionally colored as languriids, but antennal club usually 3 segmented (rarely 4-5 segmented). The antennae are 11-segmented.

Larvae and adults occur in fungi and/or rotten wood. Adults are nocturnal. Fungal feeding forms may be beneficial as diets include fungi causing heart-rot. Can be collected by bringing fungus into laboratory and waiting to see what emerges, or by using special window-pane trap mounted on tree just below fungus.

Family Endomychidae (handsome fungus beetles):

17 genera and 35 North American species.

Oval to oblong, 1-10mm in length. Pronotum with 2 grooves at base, explanate. Tarsal formula is 4-4-4, but often appears to be 3-3-3 (third tarsal segment very small). Tarsal claws are simple. Head is easily visible from above.

Larvae on fungi, adults on fungi, rotten wood or decayed fruits, rarely on dung or carrion.

Family Coccinellidae (ladybird beetles, lady beetles, ladybugs):

57 genera and 475 North American species; about 4500 species worldwide.

They are oval to round, convex, flat on ventral surface, 0.8-10mm in length. The tarsal formula is apparently 3-segmented (actually 4-4-4, but with 3rd very small and concealed in lobed 2nd segment), tarsal claws usually toothed or cleft. The antennae are 8-11 segmented, with weak club of 3-6 segments. The head is often concealed from above by the expanded pronotum. They are typically spotted, rarely striped or monochromatic.

As a group, they are beneficial, but there are injurious species in the subfamily Epilachninae (Mexican bean beetle [8 spots on each elytron], squash beetle [12 spots on each elytron], and alfalfa lady bird beetle). Other 5 subfamilies composed of entomophagous or rarely mycetophagous species. Beneficial species usually predators on aphids or scale insects. Several have been used in biocontrol programs (classical case is *vidalia* beetle on cottony cushion scale).

U.S. species recently revised, Gordon, J. N.Y. Ent. Soc. issue.

Superfamily Tenebrionoidea: They are often moderate to large, rarely minute. The eyes are often emarginate. The frontoclypeal suture is absent. The antennae are 11 segmented. Procoxae are often contiguous; the metacoxae are usually transverse, never excavate. The tarsal formula is usually 5-5-4, claws simple or slightly expanded at base. We will discuss 6 families.

Family Mordellidae (tumbling flower beetles):

The tarsi are 5-5-4. The body shape is distinctive (wedge-shaped, and somewhat hump-backed), and head is bent downward, and the abdomen is pointed posteriorly, extending beyond tips of elytra; most species are small, 3-7mm in length. The pronotum is margined laterally. The front coxal cavities are open behind. Most are black or mottled grey.

The adults feed on flowers, but larvae are predaceous in rotten wood. Some larvae are stem miners (sunflowers). They fly readily and they are common on flowers, especially composites.

Family Tenebrionidae (darkling beetles):

This is a very large family (5th largest in Coleoptera), with over 1000 North American species, mostly western U.S. and 20,000 species worldwide.

Frons produced over antennal sockets and into emargination of eyes (some exceptions). Antennae filiform, moniliform or clavate. Body shape variable. Most are black or brown; a few are marked with red. The tarsal formula is 5-5-4; the front coxal cavities are closed behind.

In the arid regions of the U.S., they take the place of the carabids. Nearly all are scavengers on decaying vegetation, animal dung, seeds, and cereals; some feed on living plant roots, tubers, or flowers; a few on fungi. A few are common pests of stored grain and flour (red and confused flour beetles, mealworms) and are often very destructive. Some are found in termite or ant nests.

Subfamily Alleculinae (comb-clawed beetles) - 185 North American species, two-thirds in western U.S. This used to be a separate family, but your text now includes them as a subfamily in the Tenebrionidae. The tarsal claws are pectinate. The tarsal formula is 5-5-4; and the front coxal cavities are closed behind. They are elongate-oval, black or brown beetles. Adults on flowers, foliage, on fungi, under dead bark; larvae resemble wireworms and live in rotting wood, plant debris or fungi.

Family Oedemeridae (false blister beetles):

They are slender, soft-bodied insects. The tarsi are 5-5-4, with the penultimate (next to last) segment dilated (chordate or bilobed) and densely hairy beneath; the tarsal claws are usually simple, the front coxal cavities are open

behind. Can often recognize them by the restricted pronotum near the elytra (the anterior part is broader). The pronotum has rounded lateral margins.

Adults occur on flowers and foliage, where they feed on pollen. Not much is known about larvae. Some species breed in driftwood (especially of conifers).

Family Meloidae (blister beetles):

Over 300 North American species.

Elongate, soft-bodied. Tarsal formula is 5-5-4, claws each with a lower blade, tooth, or spine; the front coxal cavities are open behind. The thorax is narrow, the pronotum is rounded laterally. The head is somewhat deflexed with narrow neck. Some species are metallic colored.

Adults are phytophagous (some do not feed), and sometimes are pests on alfalfa. Larvae are usually parasitic (hosts include the immature stages of wild bees and the eggs of grasshoppers).

The larvae have several different forms in development (hypermetamorphosis). The 1st instars (triungulin) are found on flowers where adults have laid the eggs. This larval form is active and will climb on bees visiting the flowers, which will then carry them back to their nests. Later instars are different, more sessile.

Adults will exude "blood" from knees and soft body parts. This contains material called cantharidin, which is a defensive chemical secretions (may have some pheromonal activity in primitive species); there is cantharidin in Spanish fly (used to be thought to be an aphrodisiac), a chemical produced in the accessory glands of males and transferred to the female during mating (now used in medicine as a counter-irritant). This is the substance that can cause blisters. This substance is very toxic to horses. If a horse eats one or two of these beetles, it can kill the horse.

Family Anthicidae (antlike flower beetles):

Small, 2-6mm in length. They are somewhat antlike in appearance. The head is deflexed with a strongly constricted "neck." Eyes are entire (not notched). Some species have a pronotal horn extending forward over head; the pronotum is rounded laterally. The tarsal formula is 5-5-4; the front coxal cavities are open behind.

Beetles found on flowers. Larvae in vegetable debris; some larvae are phytophagous on live plants. One species is predaceous

Superfamily Chrysomeloidea: The tarsal formula is apparently 4-4-4 (it is actually 5-5-5 with the 4th segment very small and concealed in lobed 3rd segment). The antennae are usually filiform or clavate (at least not usually truly clubbed). We will discuss 2 families, both of which are quite large.

Family Cerambycidae (longhorned beetles):

There are 4000 genera and 35,000 species worldwide; 303 genera and 956 species in North America; 73 species in North Dakota. This is another favorite group of beetle collectors.

The antennae are filiform, usually more than half as long as body (hence the common name); the first antennal segment is at least 5 times as long as second. The eyes are often emarginate. The body is usually elongate and parallel-sided; usually over 12mm in length. The tarsal formula is rarely 5-5-5.

The taxonomy of this group is quite good in the U.S. because there have been several important workers in recent years. All are phytophagous. Most adult cerambycids, particularly the brightly colored ones, feed on flowers and help pollinate some plants; they are the most important of all beetles in plant pollination. Many, usually not brightly colored, are nocturnal in habit and during the day may be found under bark or resting on trees or logs. Most larvae are wood boring (round-headed borers, because their burrows in wood are circular in cross-section vs. oval in the Buprestidae), and many species are very destructive to shade, forest, and fruit trees, and to freshly cut logs. A few girdle twigs and lay eggs just above the girdled band, and some bore into the stems of herbaceous plants. Some can cause serious defects to lumber and even destroy timber for commercial purposes, but they also play an important role in forest ecology by aiding in decomposition of dead and dying trees.

a. Subfamily Parandrinae: Tarsal formula is distinctly 5-5-5. Look very similar to the Lucanidae, but stag beetles have clubbed antennae. Be careful - the antennae are short.

b. Subfamily Aseminae: Not required. These are flat, and have short antennae. The eyes are emarginate or completely divided.

- b. Subfamily Prioninae: This subfamily contains the largest North American species (up to 75mm).
Antennae may be serrate. Front coxae transverse, rest usually globular. Most have teeth on the lateral margin of the pronotum, which is margined laterally (others have rounded margins).
- c. Subfamily Lamiinae: They have a vertical face. Pronotum usually a little narrower than base of elytra.
The terminal segment of maxillary palps is usually pointed. This subfamily includes some important economic species. The sawyers (pine sawyers) in *Monochamus*. They have long antennae. *Saperda* (round headed apple tree borer, elm borer); *Tetraopes* [name means 4 eyes] (milkweed borer); twig girdlers.
- d. Subfamily Lepturinae: These have broad shoulders (or the elytra is tapered or narrowed posteriorly).
Terminal segment of maxillary palps blunt or truncate. Fore coxae conical; eyes not surrounding base of antennae. They are often brightly colored and found on flowers.
- e. Subfamily Cerambycinae: Includes black locust borer. The elytra is parallel sided, and the eyes are very emarginate. Terminal segment of maxillary palps blunt or truncate. Fore coxae variable, but usually not conical. Also includes *Megacyllene powersi*.

Family Chrysomelidae (leaf beetles):

This is the 4th largest family with 1500 spp.

The antennae are usually less than half as long as body, filiform, serrate or clavate. The eyes are usually entire. The shape is variable; most are less than 12mm. The tarsal formula is apparently 4-4-4, 3rd bilobed or entire in most Chrysomelinae.

The adults and larvae are phytophagous, feeding on living plants, mostly herbaceous ones. Adults feed on leaves, the larvae usually on roots although some are free feeders on foliage (Colorado potato beetle), some are leaf miners, and some bore in stems. Most (except certain crop pests) feed only on particular plants. Many members of this family are serious pests of cultivated plants.

- a. Subfamily Bruchinae (seed beetles): This used to be a separate family, but your text book now includes them as a subfamily of the Chrysomelidae. The body is oval, often somewhat narrowed anteriorly, usually less than 5mm; the head is deflexed, often not visible from above; the antennae are usually clavate or serrate, sometimes pectinate; the eyes are usually notched; the anterior end of the pronotum is usually relatively narrow; the elytra striate; and the elytra is short exposing the pygidium. The larvae of most bruchids feed inside various seeds, especially legumes. Adults generally oviposit on seeds that are fully developed or nearly so, but some oviposit on flowers or young fruit. Some develop in stored dry seeds. Some, particularly those attacking leguminous plants, are serious pests. Adults on foliage and flowers of host plants--beans, peas, cowpeas, seeds of honey locust tree, palm, or reared from seeds and seedpods collected in field.
- b. Subfamily Donaciinae: These are the long-horned leaf beetles (similar to cerambycids). The antennae are somewhat longer than in most chrysomelids; the head usually has a deep median groove between the eyes. The pronotal margins are rounded. Often are somewhat metallic. *Donacia* - the larvae feed on submerged parts of aquatic plants.
- c. Subfamily Chrysomelinae: Examples are Colorado potato beetle; yellowmargined leaf beetle (crucifers; turnip, mustard, Chinese cabbage); cottonwood leaf beetle; *Gastrophysa* spp.; *Calligrapha* spp.; *Labidomera* spp. Third tarsal segment not always lobed. Head sunk into prothorax.
- d. Subfamily Galerucinae: These are often somewhat soft-bodied. The pronotum is margined laterally. the antennal insertions are narrow. Examples are *Diabrotica* - banded cucumber beetle, spotted cucumber beetle/southern corn rootworm; *Acalymma* - striped cucumber beetle (feeding damage to cucurbits; vector cucurbit wilt; larvae feed on roots); bean leaf beetle (soybeans); elm leaf beetle and larger elm leaf beetle. The subfamily Alticinae has now been incorporated into the Galerucinae. These are the flea beetles. The adults feed on foliage and eat tiny holes in leaves; the larvae feed on roots; a number are important pests of garden and field crops: palestriped flea beetle; *Agasicles hygrophila*, controls alligatorweed; *Phyllotreta* spp.
- e. Subfamily Hispinae: These are the leaf-mining leaf beetles. They have distinct ridges that border rows of punctures; some have rather clubbed antennae. They are somewhat narrowed. Head & mouthparts ventral and directed ventrally or posteriorly. It is the larvae that mine in leaves. The subfamily Cassidinae has now been incorporated into the Hispinae. These are the tortoise beetles. Some are

shaped like lady beetles; the pronotum and elytra have wide margins. The head is opisthognathous, and concealed by pronotum. Adults and larvae feed principally on morning glories and related plants, including sweetpotato. Larvae have forked appendage at tip of abdomen to which are attached cast skins, debris, and excrement; held over body much like parason. Golden tortoise beetle (golden reflections only when alive; dull yellow orange in death).

Superfamily Curculionoidea (= Rhynchophora): The head is more or less prolonged into beak or snout (except Anthribidae, Platypodidae, Scolytidae). The gular sutures fused or lacking (exc. Nemonychidae). The prosternal sutures are absent (exc. Anthribidae). The tarsal formula is 4-4-4 (actually 5-5-5 with 4th segment very small and concealed in lobed third segment).

Family Anthribidae (fungus weevils):

They are usually elongate-oval, compact. The head is usually not prolonged into a beak. The antennae are straight, usually 11-segmented with a 3-segmented club (rarely 4-5 segmented club); some have long antennae. The base of the pronotum is truncate with antebasal transverse ridge, this often turned forward at sides forming short keel-like lateral margins. The tarsal formula is apparently 4-4-4 or 3-3-3 (actually 5-5-5, 2nd segment apically emarginate and partially enclosing 3rd segment which is bilobed; 4th minute). The pygidium is partially exposed in posterior view, but usually invisible from above.

The adults are usually found on dead twigs or beneath loose bark. Larvae vary in habit; some breed in woody fungi, some breed in fungi of certain crops (e.g., corn smut), some feed in seeds, and a few bore in dead wood. The coffee bean weevil is an important pest of seeds, berries, and dried fruits.

Family Attelabidae (rose curculio):

Tooth nosed - have teeth on edges of mandibles; antennae not elbowed. The old traditional Rhynchitidae also is included in this family

Family Brentidae (straight-snouted weevils):

They are elongated and parallel-sided; the prothorax is pear-shaped. They have a long beak (longer in the females). The antennae are thread-like.

This is not an important economic group, but they are interesting. The larvae bore into oak, poplar, and beech (sometimes live trees). The adults are often found under loose bark. Some are myrmecophilous, probably feeding on Ambrosia fungi.

Subfamily Apioninae (apionid weevils) - This used to be a separate family, but your text now includes this group in with the Brentidae. They are pear shaped, usually blackish in color; antennae not elbowed. The sweet potato weevil, *Cylas formicarius elegantulus* (Summers) belongs in this subfamily. Larvae bore in vines and roots (most on legumes), and plants often killed. May emerge after harvest.

Family Curculionidae (weevils):

A large family, 4500 genera and 50,000 species worldwide; more than 2500 species in North America; 240 species in North Dakota.

Most species have fairly well-developed snout. Antennae usually elbowed with compact terminal club; basal segment often received in grooves on snout.

Almost all weevils are plant feeders, and many are serious pests. Almost every part of a plant may be attacked, from the roots upward. The larvae usually feed inside tissues of plant, and adults drill holes in fruits, nuts, and other plant parts. There are 33 subfamilies. Some species are parthenogenetic. Some species are used in the biocontrol of weeds, both aquatic and terrestrial.

There are lots of subfamilies, you will need to know two of them:

* Subfamily Brachyderinae: *Graphognathus* spp., whitefringed beetles. Broadnosed, flightless, parthenogenetic, introduced from Argentina. Serious pest of field and garden crops and ornamentals. Clover root curculio.

* Subfamily Eremninae: rice water weevil.

* Subfamily Cyliindrorhininae: vegetable weevil attacks many vegetables.

- * Subfamily Hyperinae: *Hypera*, 4 spp., all introduced. alfalfa weevil, clover leaf weevil, clover head weevil, lesser clover head weevil. Larvae feed externally in cooler parts of year.
- * Subfamily Hylobinae: pales and pitch eating weevil--conifer seedlings.
- * Subfamily Pissodinae: conifers. *Pissodes* tunnel in and kill terminal leader, lateral takes over and tree develops bend in trunk.
- * Subfamily Otidoccephalinae: antlike weevils, *Myrmex*, some in cynip galls on oak, in mistletoe, dead & dying twigs of sycamore.
- * Subfamily Curculioninae: *Curculio* - acorn & nut weevils, e.g. pecan, live oak.
- * Subfamily Anthonominae: fruit and seed weevils; boll weevil, pepper weevil, strawberry weevil.
- * Subfamily Cryptorhynchinae: beak at rest in prosternum. The plum curculio in plums, other fruits.
- * Subfamily Rhynchophorinae: billbugs (corn and grasses). Poultry. Grain weevils - rice and maize, stored grain.
- * Subfamily Platypodinae (pin-hole borers): 1 genus & 7 spp. in U.S. This used to be treated as a separate family, but your text book now includes them as a subfamily of the Curculionidae. Antennae short, geniculate (elbowed), with large unsegmented club. The tarsal formula is 5-5-5, the 1st segment is as long as the next 3 combined. Elongate, slender, cylindrical, brown beetles. These beetles are wood-boring and bore in living trees, but seldom attack a healthy tree; they attack both deciduous trees and conifers. Larvae feed on fungi that are cultivated in their galleries.
- * Subfamily Scolytinae (bark beetles, ambrosia beetles): This also used to be treated as a separate family, but now your text book includes them as a subfamily of the Curculionidae. There are 6000-7000 species worldwide; about 550 species in North America. The body is stout, elongate-slender, cylindrical, and usually uniform in color (brown or black). They are relatively small (6-8mm). The antennae are short, elbowed, with a large club which is usually annulated, rarely unsegmented. The tarsal formula is apparently 4-segmented (5-5-5, 4th very small). The eyes are oval, emarginate, or divided. The head is covered by the pronotum or not; the pronotum may have the anterior dorsal surface roughened or rasp-like; the elytra distally with or without spines. Bark beetles live within bark of trees, usually right on surface of wood and feed on phloem tissue. Some species deeply score the sapwood and are often called engravers. All feed in dying trees, but some species may infest living trees, especially conifers, and kill them (southern pine beetle). They may build up after hurricanes or logging operations or drought. Tree death may occur either by girdling or by fungi introduced by adults and spread by larvae which clogs water transport vessels. Have ability to attack a tree en mass, overwhelming tree's defenses. Ambrosia beetles bore into wood of living or freshly killed trees and feed on fungi (ambrosia) they cultivate in their galleries. Fungus stains wood, reducing its value. Bark beetles have a greater impact economically on timber-producing forests of North America than any other group of insects. southern pine beetle, black turpentine beetle. *Ips*, 3: small southern pine engraver, eastern fivespined ips, sixspined ips. Smaller European elm bark beetle, introduced, transmits Dutch elm disease which completely eliminated American elms in many urban areas. *Xylosandrus*, 3 spp. into U.S. and La.