Today we begin discussion of the Hexapoda, the 6-legged arthropods. Characters that distinguish the hexapods from all other arthropod groups:

1) Three distinct body regions (head, thorax, abdomen). Legs (3 pairs) on thorax.
2) One pair of antennae (rarely no antennae).
3) Mouthparts: 1 pair of mandibles, 1 pair of maxillae, a hypopharynx, and a labium.
4) Genital openings located near posterior end of abdomen.
5) No locomotor appendages on abdomen of adults.

Once again there has been quite a few changes in the phylogeny and classification of insects. Many of these we will discuss when we get to the various groups. But much of the difference in opinion involves the lower or more primitive orders that we will be discussing today. For this discussion it will be helpful for you to look at and study figure 6-1 (p. 156) in your text. This was taken from a very interesting article by Wheeler *et al.* (2001).

The Hexapoda is thought to have arisen from a myriapod type ancestor that had paired leg-like appendages on each body segment. The head region became more modified, the next three body segments behind the head formed the thorax, primarily associated with locomotion, and the leg-like appendages were lost on the abdomen. The first hexapods were wingless, and as such, they are sometimes referred to as the Apterygota. Today we will be looking at the five groups that traditionally formed the Apterygota within the Insecta. You will notice that I referred to these as groups rather than Orders. Again, some people consider these to be Orders while others now consider some or all of them to be Classes.

The first three primitive orders (Protura, Collembola, and Diplura) used to be considered as insects, but are now thought to be different enough to be separated from the Insecta. They are all characterized by having internal mouthparts, that is, the mouthparts are contained or hidden within a pouch on the head; hence, they are collectively called the Entognatha. The rest of the hexapods have external mouthparts; they are often called the Ectognatha.

Your text book then includes all of the remaining orders (including 2 more apterous orders) in the Insecta. Within the Insecta, another order is separated away also on the basis of mouthpart morphology. In the Microcoryphia each mandible has only a single point of attachment or articulation (Monocondylic), and are sometimes referred to as the Archaeognatha. In all of the remaining insectan orders, the mandible has 2 points of attachment, and they are called the Dicondylia. The Thysanura are different from the remaining insect orders by being primitively wingless, and so are sometimes called the Zygentoma. All of the remaining orders are then sometimes called the Pterygota.

PROTURA

These are commonly called proturans or telsontails. The order name means "first" (Prot-), "tail" (-ura). They are ametabolous.

Protura were first discovered in 1909. They are known worldwide and there are about 200 known species. There are about 20 species in North America. These do occur in the Fargo area.

They are usually whitish in color and are very small (0.5-2.0mm), in fact, they are relatively difficult to see even under the microscope. They are somewhat elongate in shape. The head is prognathous, and the mouthparts are entognathous and suctorial. Eyes, ocelli, and antennae are lacking (pseudoculi may represent vestigial antennae). The front legs are carried in a forward position and have gained a sensory function. They are primitively wingless. The tarsi are one-segmented with single apical claw and a bristle-like terminal pad. The abdomen bears styli on the first 3 segments, and lacks cerci.

The metamorphosis is slight (called anamorphosis):Traditional thoughts: the first instar (called a protonymph) has 9 abdominal segments; the 2nd instar (called a deutonymph) has 10 abdominal segments; the 3rd instar (called a tritonymph) has 11 abdominal segments; and the adults have 12 abdominal segments. More recent studies: prelarva (9 segments), larva I (9 segments), larva II (10 segments), maturus junior (12 segments), preimago (12 segments), and imago (12 segments).

Respiration is primarily cutaneous, that is, without the use of trachea.

Protura are easily overlooked, due mainly to their small size; they are not that rare. They are best found in moist soil, in peat, in deciduous woodland litter, and in turf. They are also found under stones and beneath bark. They feed mainly on decomposing organic matter. The best way to collect them is in Berlese funnels.

Your data sheet lists the 3 North American families. You should recognize these families as Protura, but you do not have to identify proturans to family. We do have examples in the laboratory and you should be able to identify them as a proturan.

COLLEMBOLA

The Collembola are commonly called springtails, and they are the oldest known hexapods. Soft bodied insects, such as the Collembola, do not preserve well in the fossil record, but we do have fossil evidence of already advanced Collembolans from the Devonian period.

The name Collembola means glue (coll-), for the collophore, wedge (-embola). These were first described by DeGeer, a contemporary of Linnaeus. He believed that the collophore made glue to enable the insects to stick to a surface. The collophore is a tube-like structure that we now believe to be involved in the uptake of water.

The Collembola are very small, and somewhat tubular or globular. The mouthparts are entognathous. The eyes, when present, are in the form of eye patches, consisting of up to 1 to several lateral ocelli. The antennae, when present, are usually relatively short and filiform, usually 4-segmented. They lack wings. Although trachea are present, respiration is mainly cutaneous.

The abdomen is 6-segmented, with the collophore on the 1st segment, the tenaculum [your book calls it the retinaculum] on the 3rd segment, and the furcula on the fourth segment. The furcula is a forked structure that catches on the tenaculum; when force is applied downward by the furcula, it eventually springs free of the tenaculum, hits the substrate and propels the insect into the air. Hence, the name springtails. Not all Collembola have all of the above parts.

Collembola are very common, but they usually are not observed by the non-entomologist. They are small, usually less than 5mm, and are found in the soil, decaying vegetation, leaf litter, under bark, etc. They also can occur in the nests of ants and termites. Some species are marine [*Anurida maritima* (Hypogastruridae) is daily submerged by each tide]. Collembola are rare in dry habitats. Some species, called snow fleas, can be active when there is snow on the ground; they feed on algae growing on snow drifts. They are world-wide in distribution (about 6000 species). There are about 800 species known from North America.

There have been some differences in opinion as to the number of families that should be recognized, but your text recognizes 11 families. The two synopsis handouts give the main characters of the most common families. Here in lecture, I will briefly mention 8 families; in laboratory you will be expected to be able to recognize 5 of the families.

I. Suborder Symphypleona: In this suborder the 4 basal abdominal segments are fused and indistinct, and the 5th and 6th abdominal segments are small and papilla-like (in the Sminthuridae). This suborder contains 3 families in which most of the species are all short and globular in shape. There is one new family, the

Mackenziellidae which contains a single species (northern Canada, Old World), that is not short and globular, but you will not have to know that species.

A. Family Sminthuridae: These collembolans are oval or globular in shape. The abdominal segments are fused so as to look like one large segment, plus they have a dorsal papilla. The antennae are longer than the head and distal segment often annulate, and the eyes are present. The family includes the economic pest, the garden springtail, and in Australia, the lucern flea. Some species have elaborate mating rituals. There are about 100 North American species.

B. Family Neelidae (not required): These appear similar to the sminthurids in that the abdominal segments are fused, so as the abdomen is oval or globular. In contrast to the sminthurids it has the antennae shorter than the head, and it lacks eyes. They are usually smaller than the sminthurids. There are about 7 North American species.

C. Family Mackenziellidae (not required): Third and fourth abdominal segments are fused as in the above two families, but the body is more slender and elongate, not short and globular. The antennae are elongate as in the Sminthuridae, and the eyes are usually present. There is only 1 species occuring in the Old World and in northern Canada.

II. Suborder Arthropleona: These collembolans are more elongate and slender. There are 6 distinct abdominal segments (they are not fused).

A. Prothorax visible from above:

1. Family Poduridae (not required): The abdomen is elongate with 6 distinct segments, and the furcula is present, elongate, and well-developed; the prothorax is not reduced, so it is visible from above; the antennae are about the same length as the head or longer; and the eyes are usually present. They are very small, and are usually gray, black, or purplish in color. There is only one species in the U.S., *Podura aquatica*, a species that lives on the surface of freshwater ponds. There are some who now believe that this family may actually be more closely related to the Sminthuridae and Neelidae.

2. Family Hypogastruridae: The abdomen is elongate with 6 distinct segments; the prothorax is visible from above; the antennae are shorter than the head; and the eyes and furcula may or may not be present; if the furcula is present, it will be quite small. This is the largest family in the U.S. with over 200 North American species. It contains the snow flea, *Hypogastrura nivicola*, which will feed on algae growing on snow in the winter. It also includes the marine species mentioned previously.

3. Family Onychiuridae: The abdomen is elongate with 6 distinct segments; the prothorax is visible from above; the antennae are shorter than the head; the eyes and furcula are absent; and the cuticle has a pattern of clear circles (pseudocelli); and there is usually a post-antennal organ. When disturbed they have the ability to exude their hemolymph through the pseudocelli which is noxious. There are 85 N. Am. species.

B. Prothorax not visible from above:

1. Family Entomobryidae: The abdomen is elongate with 6 distinct segments, but the 4th segment is at least twice as long as the 3rd segment; the prothorax is reduced, so that it is not visible from above; and the antennae are relatively long. These are the largest springtails; the furcula is well-developed. There are about 138 species in North America. This is a fairly large group of relatively diverse insects - several small groups have been separated out of this family to form their own families. These are generally more rare, and most do not occur in our area, but you should be aware that just

because the 4th abdominal segment is elongate, this may not be a guarantee that you have an entomobryid. More recently, this family has been split into several different families.

2. Family Isotomidae: The abdomen is elongate with 6 distinct segments, with the 3rd and 4th segments of nearly the same length; the prothorax is not visible from above. There are about 200 North American species. Some isotomids undergo ecomorphosis, which is the production of different morphological forms caused by different temperatures. There is at least one species which is carnivorous on other springtails.

DIPLURA

These are commonly called diplurans, japygids, or campodeids. The order name means two-tailed and refers to the 2 conspicuous cerci at the posterior end of the abdomen. The metamorphosis is ametabolous with the immatures resembling the adults, just being somewhat smaller.

These are small to medium-sized, usually pale in color. The mouthparts are entognathous, in a pouch-like structure, and they are chewing. They lack compound eyes and ocelli, and the antennae are relatively long and many-segmented. The wings are lacking, and the tarsi are 1-segmented. They have tracheae, but no Malpighian tubules [a character which some workers feel should remove them from being true insects]. They have the 2 caudal cerci, but lack a median caudal filament; the cerci may be forceps-like or more filiform. They also lack scales on their bodies. Styli are found on most abdominal segments.

Some authors combine this group with the Thysanura, but the absence of a median caudal filament, the absence of scales on the body, and the entognathous mouthparts will readily separate this order from the Thysanura.

They are most often found in soil or leaf litter, and sometimes under bark or in rotten logs. The best chance of collecting these is in the Berlese samples.

There is some resemblance of these to symphylans. You should compare diplurans with the symphylans to make sure you can separate the two.

There are 5 North American families of Diplura. Once again, I will briefly mention all five in lecture, but you will only be responsible for recognizing the Japygidae and Campodeidae in laboratory.

A. Family Japygidae: This group is relatively easy to recognize because of the forceps-like cerci, and the presence of trichobothria on the antennae. In general, the only other insects with forceps-like cerci are the earwigs (Dermaptera) which are much bigger and usually have wings. Some species occur in caves. A friend of mine at LSU just described a large cave-dwelling species in a recent issue of the Annals. There are about 28 species in North America. These do occur in North Dakota in the Fargo area.

B. Family Parajapygidae (not required): Also has forceps-like cerci, but does not have trichobothria on the antennae. Two genera and about 6 species in North America.

C. Family Campodeidae: In this group the cerci are not forceps-like, but they are relatively long, about as long as the antennae, both of which are about one-half the length of the body. This is the most common family. There are about 34 North American species and they do occur in the Fargo area. [Note: one of the immature insect body types is referred to as campodeiform - it is named after the shape of the insects in this family].

D. Family Anajapygidae (not required): In this group the cerci are not forceps-like, and they are relatively short, much shorter than the antennae. They have styli on abdominal segments 1-7, and the

antennal trichobothria begin on the 5th antennal segment. There is only one rare species which is only known from Placer Co., California.

E. Family Procampodeidae (not required): In this group the cerci are not forceps-like, and they are shorter than the antennae. They lack styli on abdominal segment 1 (present on segments 2-7). The trichobothria begin on antennal segment 3. This family is also quite rare with only one North American species which is also known only from California.

MICROCORYPHIA

These are commonly called the jumping bristletails. The order name means small (Micro-) head (-coryphia). The metamorphosis is ametabolous. They are very similar in appearance to the Thysanura (or silverfish) and used to be included within that order [the older versions of your textbook included them in the Thysanura]. They are somewhat more cylindrical than the thysanurans and the thorax somewhat more arched, and they have only a single point of articulation between each mandible and the head (there are 2 in thysanurans).

In fact, this single point of articulation between each mandible and the head is the foundation for another name often used for this group, the Archeognatha.

Jumping bristletails have 3 caudal appendages, the 2 cerci and a median caudal filament. They are ectognathous, that is the mouthparts are now external. The compound eyes are large and contiguous, and ocelli are always present. The antennae are relatively long and filiform; the wings are absent. The middle and hind coxae bear styli, and the tarsi are 3-segmented. The abdomen bears a pair of styli on segments 2-9. Most abdominal segments bear 1-2 pairs of eversible glands. These eversible glands function as water-absorbing organs. The bodies are usually covered with scales.

They have the habit of cementing themselves to the substrate before they molt; if they come loose from the substrate they will not be able to complete the molt and will die.

These are relatively active insects and will jump when disturbed. They feed chiefly on algae, but will also feed on mosses, lichens, decaying fruits, and similar materials.

There are only 2 families, of which you will only be held responsible for the Meinertellidae in laboratory.

A. Family Machilidae (not required): In this group the two basal antennal segments are heavily scaled, and the abdominal sterna are relatively large. There are at least 1 pair of eversible glands on most abdominal segments. There are about 20 species in North America.

B. Family Meinertellidae: In this group the antennae lack scales, and the abdominal sterna are reduced. There is at most 1 pair of eversible glands on each abdominal segment. There are only about 5 North American species, but they are widely distributed. Has been collected in the Fargo area, but not recently.

THYSANURA

These are commonly called the silverfish and firebrats. The common name of the order means bristle tail and refers to three caudal appendages. Their metamorphosis is ametabolous.

They are similar in appearance to the Microcoryphia, but they are somewhat more flattened than those insects. Also, the compound eyes may be absent, but when they are present they are much smaller than that seen in the Microcoryphia; the ocelli may or may not be present. They also lack the styli on the middle and hind coxae which are present in the Microcoryphia. They are usually covered with scales; the head is prognathous with the mouthparts ectognathous and chewing. The mandibles now have two points of articulation (called

Dicondylia). The antennae are elongate, filiform, many-segmented. They lack wings, and the tarsi are 3-5 segmented. They have 11 abdominal segments which most bear styli; they do have the 3 caudal appendages: a pair of cerci and a median caudal filament.

Most species live in soil and leaf litter or rotting wood. There are several species, however, that live in human dwellings, the silverfish and firebrats. In fact, these are generally considered to be pests.

The styli are probably vestiges of locomotor appendages. This group is also interesting in that some species will continue to molt even after reaching adulthood.

Your book covers 3 families; you will be responsible for only one of these in the laboratory, the Lepismatidae.

A. Family Lepidotrichidae (not required): In this family the tarsi are 5-segmented, and the ocelli are present. The body lacks scales. It contains one rare species which occurs in northern California.

B. Family Nicoletiidae (not required): In this family the tarsi are 3 or 4-segmented. The compound eyes and ocelli are absent. The body may or may not be covered with scales. Some of these are elongate with long cerci and antennae, and others are more oval in shape with the antennae and cerci shorter. Some species occur in caves and mammal burrows, while others live in ant or termite nests. There are 5 North American species known from Florida and Texas.

C. Family Lepismatidae: In this family the tarsi are 3 or 4-segmented. The compound eyes are present, but the ocelli are absent. The body is covered with scales. There are 14 North American species. It includes the silverfish, *Lepisma saccharina*, and the firebrat, *Thermobia domestica*. Both of these do live in buildings where they feed on starchy substances. They will feed on book bindings, starched cloths, wallpaper paste, etc. The silverfish is gray in color and is found in cool, damp situations. It has the lateral cerci sticking out at right angles to the body. The firebrat is tan or brown in color; prefers warm situations; and has the lateral cerci pointing more to the rear. Other lepismatids occur in caves, in debris, under stones and leaves, and in ant nests. We may be getting both species in the building.