Entomology 311 Lab Manual

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Contents

ENT 311 – Integrated Pest Management

Lab Manual – Revised 2019

Introduction

Labs in this book supplement the information gained in lecture, as well as providing some perspective and experience with hands-on applications of ideas in pest management. The labs are presented in week-by-week order, so the pre-labs and reading for week 1 are labeled "Pre-Lab 1" and "Week 1 Reading".

Pre-Labs are assignments to be done before lab meets, and will be due at the beginning of Lab. Complete the labs using your textbook, web resources, or the reading assigned for the week.

Readings are short 1-3 page "chapters" covering background topics pertinent to the upcoming lab, particular groups of insects/arthropods, or methods used in Pest Management. This should be read before coming to Lab each week.

Lab Assignments need to be printed and brought to class so that they can be completed as a group in Lab. It is sometimes helpful to read through the assignment ahead of time to get an idea of the subject matter for the week.

Expectations

Pre-labs are meant to be done before lab, helping you with the background information you'll need in order to understand and complete the Lab Assignment. You may do the Pre-labs as far in advance as you wish, though there may be information provided during class and lab that may help complete the assignments before hand – they are meant to follow the course progression of topics. Pre-labs are due in the first **5 minutes** of Lab.

Do not do the Lab assignments in advance – there may be changes to the lab due to weather, availability of facilities and other factors that are difficult to predict from term to term. For example, we can't expect to collect insects as a class every year in week 5 because springtime in Oregon rarely allows for outdoor labs on a schedule. As a result, we'll move some of the activities around to accommodate any changes that need to be made.

You must be in lab to get credit for your work. You may not give your pre-lab to a classmate to turn in, nor will pre-labs OR lab work be accepted after the due date. We meet once a week, you should have sufficient time in that week to complete assignments. If you must miss lab for personal or school-related activities, you must let me know and arrange a time to turn in your pre-lab. Lab assignments cannot be made up, as we only have one day in the classroom per week for lab time.

Bring your materials to class with you as instructed each week. If you are unprepared and cannot complete lab assignments, that will be reflected in your grade for the week.

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WEEK 1: INTRODUCTION TO COLLECTION AND CURATION

Week 1 Materials

Reading

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Pre-lab 1 Download

Pre-lab 1 .... [WEB][PDF][WORD]

Lab 1 Download

Lab 1 Assignment ... [WEB][PDF][WORD]

Week 1: Reading

Introduction to Collection and Curation

Part 1. Collection Techniques

There are many ways to collect insects, many of which do not require specialized or high-tech equipment; however, the ability to specialize in the type of insect desired by varying your collection technique. There are two main categories of insect collection techniques: **active** and **passive** collection. Active collection requires energy from the collector in order to be the most effective – that is, the collection must provide the impetus for collection. In passive collection, usually requiring a trap of some sort, there is no action needed other than simply placing the trap in an ideal position and waiting an appropriate amount of time. Read the following descriptions of active and passive trapping techniques, paying special attention to the types of insects that can be targeted with each method.

A. Sweep Net

Figure 1-1: *Sweep nets can sample from ground vegetation and aerial insects. Image source: https://www.flickr.com/photos/107640324@N05/35183817325*

Sweep netting is one of the easiest ways to survey the insects and arthropods in a particular area while also enabling the collector to focus on a particular habitat type. A sweep net can be used to sample ground vegetation or to selectively target aerial insects, like wasps and butterflies (figure 1-1).

When used to sample vegetation, a collector can gain information on plant pest densities, diversity of insects using the vegetation as a host, and presence or absence of certain parasitoids of plant pests. In general, sweep netting is most effective when the collector uses a slightly slower-than-normal pace, moving forward continuously while sweeping the net from left to right in front of them, making sure to rotate the open mouth to strike the vegetation both ways with the bell extending behind. Often, the collector will alternate different vertical strata of the vegetation as well to collect insects that prefer the leaves as well as those that may gather on flowers or seed heads – as the net moves left to right, the collector will change the angle of the net to sweep the upper and lower parts of the vegetation evenly. When sweeping, it is important to strike the vegetation with enough force that insects will be dislodged, but no so hard that the vegetation is destroyed. Once the sample is complete, the bell of the net can be flipped over the mouth, or rim, preventing escape of collected insects until the net can be emptied.

B. Kick Net

Figure 1-2: *Kick nets can sample from aquatic environments. Image source: https://commons.wikimedia.org/wiki/File:Students_use_a_kick_net_to_collect_stream_insects_(9895261295).jpg*

Kick nets are used for aquatic sampling: the net is shaped like a "D", or often triangular, so that there is one flat side of the net that can be placed flush against the substrate at the bottom of a river or lake (figure 1-2).

Kick nets work most easily in flowing water. The sample site is approached from downstream, so as not to disrupt the sample site before the sample can be taken. The net is placed flush against the substrate with the mouth of the net facing upstream. It is best if the sample location has sufficient flow to hold the bell of the net open with the current; the current must be sufficiently strong that it can flow through the net without creating backflow, as this will rinse captured invertebrates out of the net as the sample is collected. Immediately in front of the net, large stones can be lifted (still in front of the net) and scrubbed by hand to dislodge any invertebrates into the current, carrying them into the bell of the net. Once all larger stones are scrubbed and moved out of the way, the collector can use the toe of a boot to agitate the smaller gravel or sediment substrate to dislodge the invertebrates preferring this type of habitat. This "kick-sample" can be timed to regulate sample efforts in several sites to compare results.

Figure 1-3: *Beat sheets are used to collect insects in trees and hard to reach vegetation. Image source: https://commons.wikimedia.org/w/index.php?title=File:Students_use_a_kick_net_to_collect_stream_insects_(9895261295).jpg&oldid=305961611*

C. Beat Sheet

Beat sheets are used to collect insects in trees or hard-to-reach vegetation (figure 1-3). The idea is simple: a sheet is extended below the vegetation to be sampled, and the stems or branches with the desired arthropods are gently beaten, causing the vegetation to shake clinging arthropods loose. The arthropods should fall from the vegetation onto the beat sheet placed below, usually of a bright color to make the arthropods more visible, where they can be easily collected with forceps or an aspirator. As with the sweep net, it is important to use the correct amount of force with this technique to collect the highest number of arthropods possible while avoiding undue damage to the vegetation.

D. Leaf Search

It is very often that the search and collection of insects is for use in identifying pest or beneficial insects in crop systems, in which case methods that damage the vegetation in any way may not be the ideal method for sampling. These insects may also be quite small and easy to damage with a sweep net sample. With delicate or small plants and insects, a simple leaf search is an easy way to collect and count insects, as well as establish plant-insect relationships and life cycle information. Many plant-feeding insects lay their eggs directly onto host plants, where there will be readily-available food resources for newly hatched larvae or nymphs. For many species, the eggs are easy to find as well, especially if the collector is careful to inspect plant crevices and the soil just beneath host plants (figure 1-4).

Figure 1-4: *Leaf searching with forceps or an aspiration is ideal when observing and sampling delicate species on leafs. Image source: https://commons.wikimedia.org/wiki/File:Fred_Coyle_searching_for_spruce-fir_moss_spiders_(8125776694).jpg*

For this technique, gently inspect the upper surface of the leaf, disturbing it as little as possible. Then gently rotate the leaf at the stem, taking care not to dislodge any insects that may be on the underside of the leaf. Forceps or an aspiration can be used to collect, or if the insects are very small and fragile, a paint brush can be used to transfer insects into vials without damaging the specimens.

E. Pitfall Trap

There are many nocturnal arthropods that are difficult to spot and capture either because they aren't out during daytime sampling activities or because they are difficult to see in the dark when they are active. Additionally, many ground-crawling arthropods are difficult to sample in general without devoting a great deal of time to searching. For these, pitfall traps are useful for sustained sampling without a great deal of effort (figure 1-5).

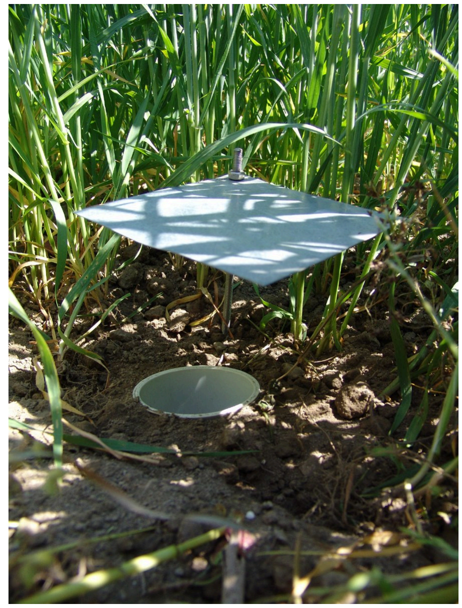


Figure 1-5: *Pitfall traps are ideal for collection nocturnal and ground crawling species. Image source: https://commons.wikimedia.org/w/index.php?title=File:Barber_pitfall_trap.jpg&oldid=269026568*

Pitfall traps are simple to construct: a cup is placed into a hole dug in the ground, with the top edge of the cup level and in contact with the soil surface (not above – this may act as a barrier and discourage insects from walking into the trap). Insects that wander into the trap fall into the cup where they are trapped until the pitfall is recovered by the collector. For live catch, a deep, dry cup is ideal to prevent escape. If the arthropods need not be live, then 1-2" of water in the bottom of the cup with a few drops of soap to break the surface tension will ensure none escape. If water and soap is used, it is important that the trap be out no longer than 24 hours before recovery to prevent the insect bodies from breaking down in the solution. If the trap needs to be out for a longer period, a preservative should be used to prevent this from happening. Recreational Vehicle (RV) antifreeze containing propylene glycol evaporates slowly, can be reused and is reasonably environmentally safe for such needs. To protect captured insects and arthropods from birds, rodents and rain, it is also suggested to place some kind of cover over the pitfall trap, leaving at least 2" of space between the ground and the cover.

F. Berlese Funnel

Figure 1-6: *Berlese funnels are ideal for collecting soil dwelling insects that like to avoid heat and light by shining a light on the top and directing them down into a sample container. Image source: https://www.flickr.com/photos/briangratwicke/4358465441*

Many soil and leaf litter –dwelling arthropods avoid light and heat, as they require damp soil conditions to prevent their own desiccation. Many of these arthropods are also quite small, making soil samples difficult to process when searching for soil-dwelling pests and their natural enemies. Berlese funnels take advantage of the natural instinct of these organisms to avoid heat and light: a soil sample is collected and placed into the inverted funnel. A light is turned on above the funnel and left, slowly heating and drying the soil sample from the top down. As the sample dries, the arthropods move down in the soil profile until reaching the bottom of the funnel, falling through a screen into a collection jar or vial. The collection vial should have a few inches of ethanol or other preservative to prevent drying of specimens, and checked regularly to prevent evaporation. Berlese funnels are easily modified for use in a variety of sizes – a Berlese funnel can be constructed of nothing more than a desk lamp and 2-liter soda bottle (figure 1-6).

G. Light Trap

Figure 1-7: *Light traps are used to collect nocturnal insects that are attracted to light and their predators. Image source: https://commons.wikimedia.org/w/index.php?title=File:Light_trap_(2145141346).jpg&oldid=273385510*

Many nocturnal insects are attracted to light; many that are not specifically attracted to light may move toward light in expectation of finding prey among those that are attracted to light. Light traps are an easy way to sample nocturnal insects – especially flying nocturnal insects – depending on the type of light used and the length of time the light is provided (figure 1-7).

Black lights are well known and often used to collect night flying moths. The most effective way to use this method is to shine a black light onto a hanging white sheet in an area where there is little to no competing light (including the moon – this works best in the two weeks either side of a new moon). The most mobile night fliers will arrive first, followed by those less mobile and the predators and parasitoids of night flyers. Trying different light types may yield more diversity in sampling. As insects come toward the light and land on the sheet, they can be collected with a net, aspirator or forceps.

H. Pan Trap/Bait Trap

Figure 1-8: *Pan and bait traps can be used to attract specific insects if you are knowledgable of their specific biology. Image source: https://www.flickr.com/photos/93467196@N02/14705662381*

Attracting insects active during the day requires knowledge of specific biology. For example, bees and butterflies are attracted to certain colors, and thus colored bowls with water and soap solution can be used to attract and trap these insects. In greenhouses, thrips and other small plant parasites that are attracted to bright colors can be trapped using yellow sticky cards, an effective sampling technique used widely for monitoring populations. For pest insects more reliant on chemoreception to locate food or mating resources, there is a wide variety of pheromone traps commercially available. Many of these traps will kill the insects upon capture (drowning in solution), if not immediately then eventually (those stuck to the sticky glue in a pheromone trap will not live long). Using different trap types in different locations may receive different results, and can even be improvised using common materials – a strip of duct tape upside down on a card left out overnight is an effective general indoor trapping method for capturing spiders and other infrequently-encountered inhabitants of human structures (figure 1-8).

Traps can be modified to specify arthropods attracted – for example, placing carrion will attract a completely different assemblage of arthropods than pan traps.

Part II. Preservation

Once insects are collected, there are short-term and long-term methods for preserving specimens for curation.

If insects are caught alive, it is best to have an ethyl acetate-charged kill jar available, as well as escape-proof vials, cups, or other storage containers (figure 1-9). Often, removing insects from a sweep net or live trap into a kill jar is the most difficult part of preserving specimens. The end of most nets are mesh and can be placed directly into a kill jar (provided the kill jar is large enough), and the lid screwed lightly down as far as possible should keep enough ethyl acetate around the specimen to cause temporary knock-down. At this point (usually 1-2 minutes), the specimen can be quickly removed from the net and placed into the kill jar, firmly closing the jar.

Figure 1-9: *An ethyl acetate-charged kill jar for dispatching insects that are caught alive.*

Once collection is complete, all specimens should be frozen within 12 hours to prevent fungal growth that will ruin the specimen, and to make sure the specimen is dead. Some beetle and spiders require a full 24 hours frozen to ensure death. Large, wet-bodied insects, i.e. Praying Mantis, should be frozen outside of a container to begin the drying process.

Specimens may remain in a freezer as long as needed, and following a freezing period most arthropods can be immediately pinned or placed into ethanol. Non-insect arthropods are always preserved in vials of ethanol, as well as soft-bodied, larval, or very small insects like aphids and midges. If the body of the arthropod is soft and fluid filled, it most likely will require preservation in ethanol. If the insect body has hardened cuticle, it will be preserved on a pin. General Rule: If you were to step on it, would it squish (ethanol) or crunch (pin)? Some larger insects (Large grasshoppers, mantids, large bot flies and horse flies) have enough oil and body water that they should be allowed to dry out for a few days before pinning. To prevent fungal growth, alternate 12-hr periods in and out of the freezer until sufficiently dry.

Materials: Preservative Ethanol should be diluted to a 70% for specimen preservation. If ethyl acetate is not available for kill jar charging, acetone-based fingernail polish remover is an inexpensive alternative, though it does not work as fast and will require more frequent re-charging. Kill jars can be purchased, but they can also be easily made with a jar and plaster of Paris. Once mixed, layer an inch of plaster into the bottom of the jar and allow to dry – having several kill jars available for use makes prolonged collecting easier.

Part III. Curation

Pinning: In general, the pin is inserted into the second section of the thorax, though there are few exceptions. Insertion will be into the right side of the insect (from above) to make sure that at least one complete half of the thorax will be undamaged, preventing loss of structures used in identification. Pin position is indicated on the diagram below for the different insect body types (figure 1-10).

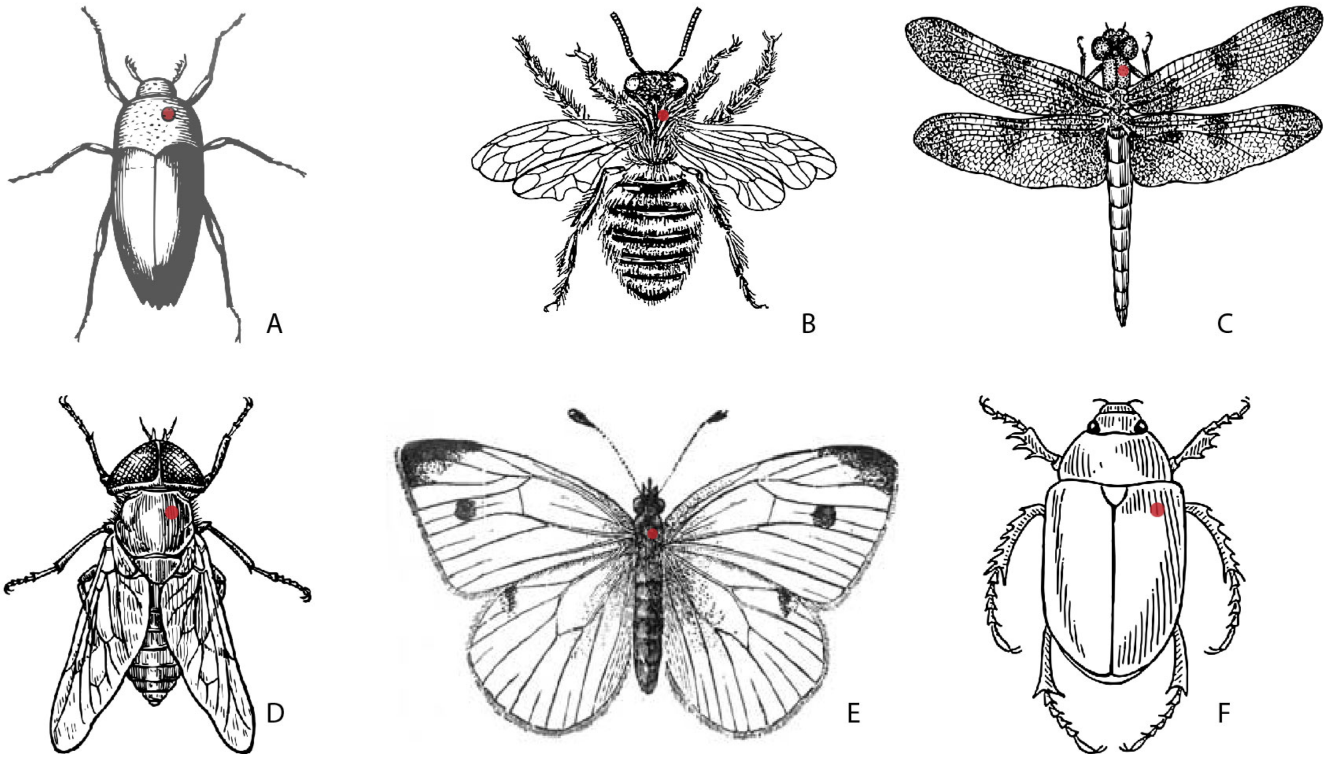
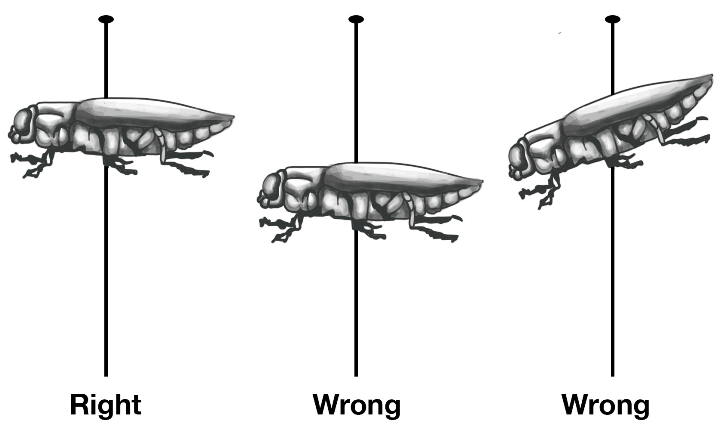


Figure 1-10: *Diagram of ideal location to pin insects by type.*

The height of the insect on the pin is easily spaced using a pinning block. Once the pin is in the correct position in the thorax and through the body, insert the point of the pin into the highest step of the pinning block and gently press. Make sure the insect is level on the pin, as shown below (figure 1-11) For larger insects, turn the pin upside-down into the bottom step of the block to make sure the body of the insect isn't too close to the head of the pin at the top (figure 1-12).



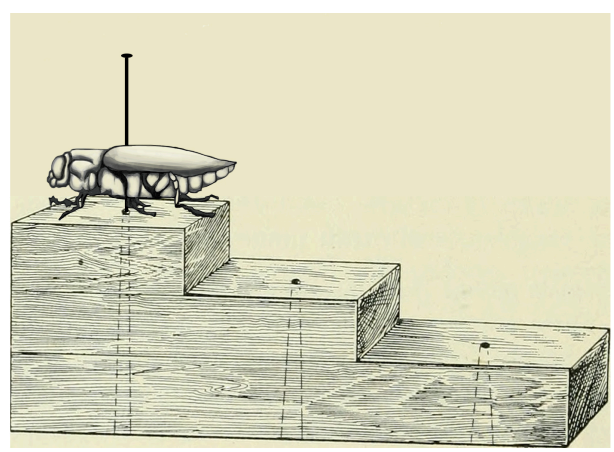


Figure 1-11 (Left): *Keep insect level on the pin.* ***Figure 1-12 (Right):*** *Pinning block use*

For insects that are too small to be pinned through the thorax without ruining the specimen, a pointed elongate triangle of paper is used. The wide end of the triangle is pinned, and the thin point is glued to the right side of the underneath of the second thoracic segment. Cardstock works best for durability, and there are specially made point punches for creating standard points (figure 1-13).

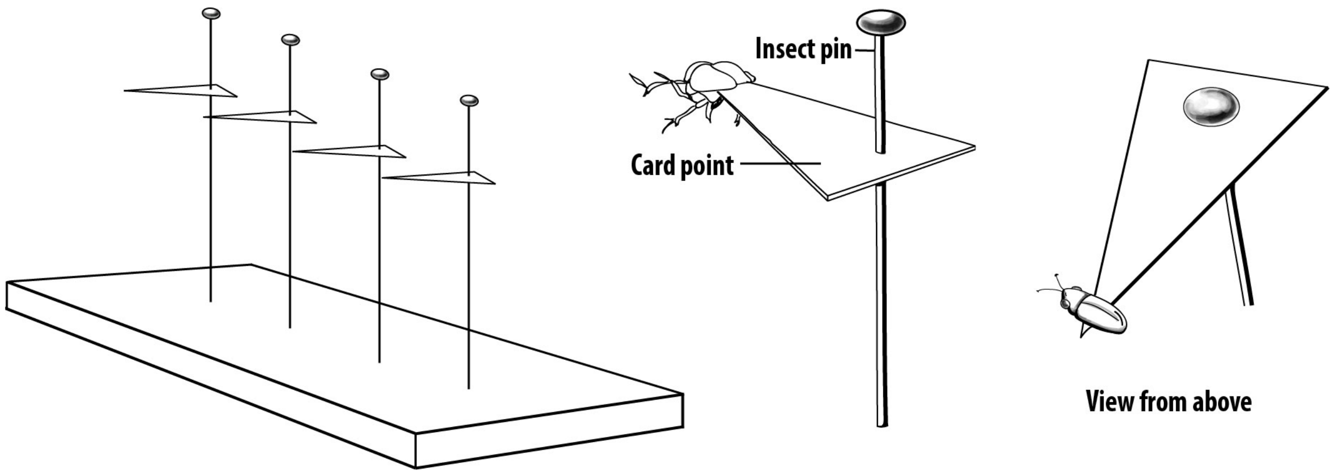


Figure 1-13: *Using Elmer's glue for pointing is fine as this glue usually dries clear. However, it is viscous out of the container, and allowing it to dry and become more sticky before use is advised. Alternatively, clear nail polish works well.*

Insects with large wings are mounted with the aid of a spreader board, which allows the curator to gently spread the wings and secure them for the drying process. The body of the insect is inserted (on the pin) into the lateral groove in the board, and strips of paper are used to gently pull the wings to the board. Using the blunt end of a pin (to prevent tearing) to gently manipulate wing joints may be helpful. Once the wing is in the ideal position, pins are inserted into the strips of paper rather than the wings themselves to avoid damage (figure 1-14).

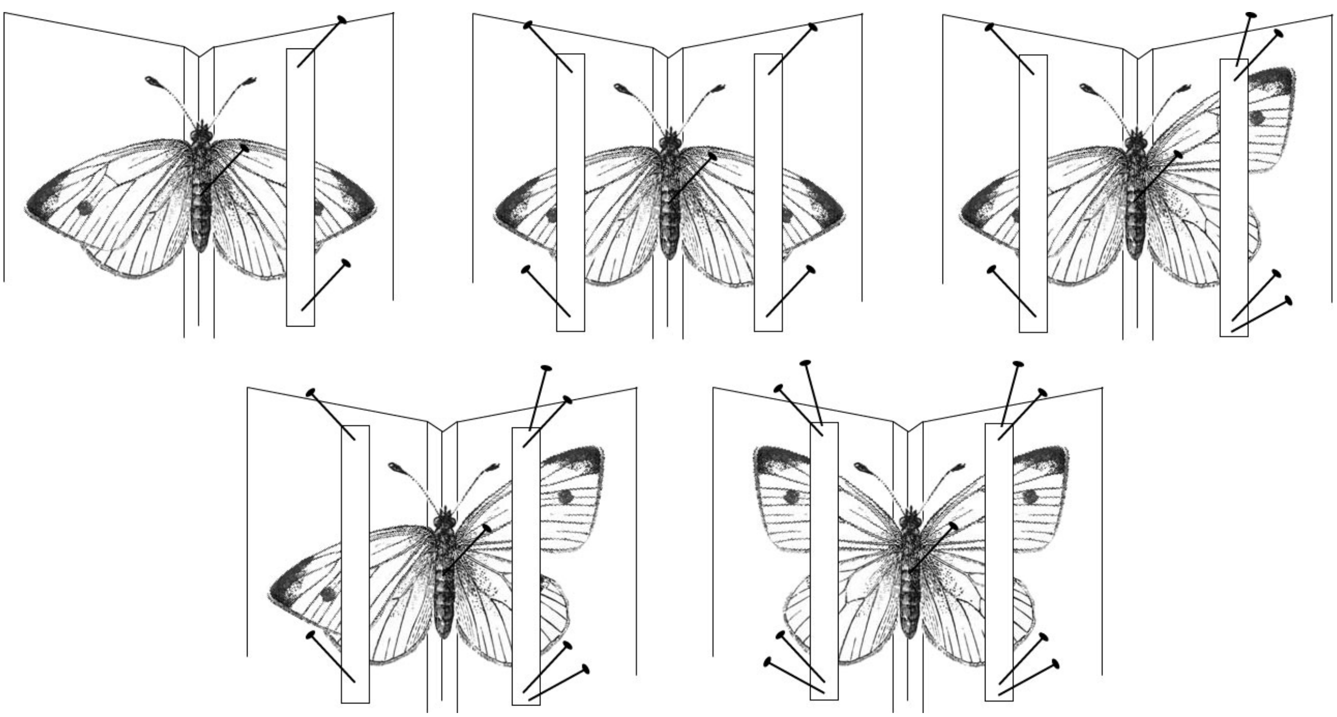


Figure 1-14: *Once pinned or pointed, the second and third step on the pinning block can be used to adjust the correct height for the two labels that will accompany the specimen.*

Ethanol storage: Non-insect arthropods, very small (too small to point), and soft-bodied insects are preserved in 70% ethanol. Only ONE kind of specimen should be placed in each vial. For large arthropods, such as large spiders, ethanol may need to be changed 2-3 times as materials leach from inside the body, causing the ethanol to cloud. For suspended or posed specimens, hand sanitizer can be used in the place of ethanol. In the case of large specimens where leaching is expected, hand sanitizer should not be used until ethanol storage ceases to cloud the fluid.

Labels

Upper Label:

Order
Family
Identified by:

Figure 1-15: *Upper label*

Lower Label:

Location Collected (County/Habitat)
Date Collected
Collected by:

Figure 1-16: *Lower label*

For pinned specimens, these labels can be created in a spreadsheet and printed for display. For ethanol specimens, the labels should be written in PENCIL on two sides of the same label rather than placing two separate labels into the vial. Labels should be INSIDE the vial with the specimen, not taped to the outside or otherwise displayed.

Pre-Lab 1: Arthropod Collection

Name: ___________________________________

Collection and Curation

Select TWO active and TWO passive techniques from the reading. For each: 1. Describe the technique; 2. Identify the types of arthropods are targeted by the collection technique.

Active #1: _______________________

Description:

Targeted arthropods:

Active #2: _______________________

Description:

Targeted arthropods:

Passive #1: _______________________

Description:

Targeted arthropods:

Passive #2: _______________________

Description:

Targeted arthropods:

Lab 1 Assignment: Arthropod Classification

Name: ___________________________________

Hierarchical Classification System

Classification systems enable us to impart order to a complex environment. In biology, organisms may be grouped according to their overall similarity (a classification method known as phenetics) or according to their evolutionary relationships (a classification system known as cladistics). Most modern scientists tend to adopt a cladistic approach when classifying organisms.

In biology, organisms are given a generic name (reflecting the genus of the organisms), and a specific name (reflecting the species of the organism). A genus is a group of closely related organisms. Genera which are closely related are grouped into a higher (less specific) category known as a family. Families are grouped into orders, and orders into classes. Classes of organisms are grouped into phyla, and phyla are grouped into kingdoms. Domains are the highest taxonomic rank of organisms.

Domain	Bacteria, Eubacteria, Eukarya
Kingdom	Plants, Animals, Fungus, Protists
Phylum	Cnidaria, Annelida, Arthropoda
Class	Insecta, Arachnida, Crustacea
Order	Coleoptera, Lepidoptera, Diptera
Family	Tipulidae, Apidae, Scarabeidae
Genus	*Scaptia, Euglossa, Anastrangalia*
Species	*beyonceae, bazinga, laetifica*

Glossary of Phylogenetic Terms

Phylogeny: interrelationships of organisms based on evolution

Systematics: the study of the diversity of organisms, which attempts to organize or rationalize diversity in terms of phylogeny

Taxonomy: the technical aspects of systematics, dealing with the formal description of species, establishing rankings of groups, and general principles of classification and naming

Phylogenetic Tree (cladogram): a diagrammatic representation of the presumed line of descent of a group of organisms. Thus, a phylogenetic tree is actually a hypothesis regarding the evolutionary history of a group of organisms.

Monophyletic Group (Natural Group, or Clade): a group of taxa which share a **derived character**. This is the only grouping which is considered relevant to phylogenetic classification.

Paraphyletic Group: a group of taxa which share a **primitive** character, thus an artificial group.

Polyphyletic Group: a group of taxa which share a **convergent similarity**, thus an artificial group.

The Arthropod Phylum

Phyla a major groups of organisms. Insects are a Class in the Phylum Arthropoda. Characteristics of arthropods include:

1. Segmented bodies 2. Jointed legs 3. Exoskeleton

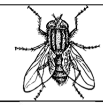
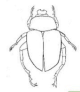
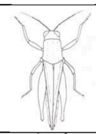
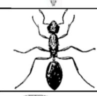
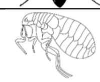
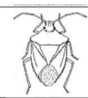
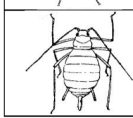
4. Open circulatory system 5. Invertebrate 6. Bilateral Symmetry

Observe the live and preserved specimens on display in the laboratory. Compare and contrast the major Arthropod classes in the table:

	Antennae (#)	**Eyes Compound/Simple**	**Legs (#)**	**Segmentation (#)**	**Mouthparts (Chew/suck)**
Arachnida					
Malacostraca					
Diplopoda					
Chilopoda					
Insecta					

Create a Phylogenetic Tree illustrating the taxonomic relationships for the following Arthropod groups: Chilopoda, Diplopoda, Arachnida, Insecta, Araneae, Acari, Opiliones, Coleoptera, Odonata, and Collembola.

There are roughly 32 Orders in the Class Insecta. We will go through a brief overview of the major orders as a group. As we go through, identify each of the photos below with the correct Order, Order common name, and at least 2 physical characteristics that separates that Order from the others.

	ORDER	ORDER COMMON NAME	DISTINGUISHING CHARACTERISTICS
			
			
			
			
			
			
			
			

EQUIPMENT CHECK-OUT
Net Number: ____________ (40)
Kit Number: ____________
Check each item after making sure it is included in your kit:
_____ Forceps (20)
_____ Paintbrush (5)
_____ Styrofoam (5)
_____ Pinning Block (20)
_____ 5 vials (25)
_____ 100 pack of insect pins
_____ Schmitt Box (20)

You are responsible for the maintenance and return of all materials at the end of the term. If items are lost or damaged, points will be taken away from your overall lab score. Point values have been assigned to each item in parenthesis above.

WEEK 2: PALEOPTERA AND THE PRIMITIVE INSECTS

Week 2 Materials

Reading

Week 2: Reading ..... [WEB]

Pre-lab 2 Download

Pre-lab 2 .... [WEB][PDF][WORD]

Lab 2 Download

Lab 2 Assignment ... [WEB][PDF][WORD]

Week 2: Reading

Paleoptera & the Primitive Insects

There are two main groups of insect orders: the **Paleoptera** and the **Neoptera.** Just as it sounds, the Paleoptera are the more ancient of the insect orders, and only two remain extant: the Ephemeroptera and the Odonata. Members of these orders are hemimetabolous, meaning that they develop in stages with no pupal stage, and that the life stages are divided by habitat: the larvae develop in aquatic habitats while the adults are terrestrial. The Ephememeroptera (Mayflies) and Odonata (Damsel and Dragonflies) both have chewing mouthparts and two pairs of wings that cannot be folded over the insect's back (no flexion), but beyond that there are few similarities (figure 2-1).

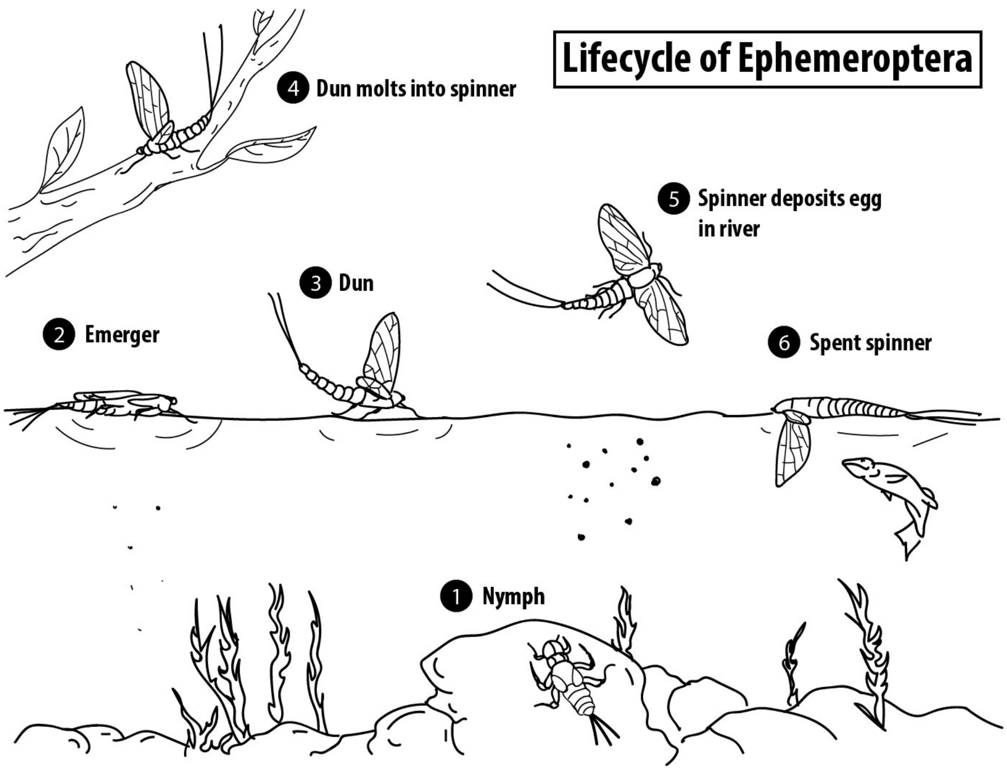


Figure 2-1: *Lifecycle of ephemeroptera.*

The **Ephemeroptera** are relatively small, delicate insects with 2-3 long terminal cerci. The majority of their life is spent developing and feeding as nymphs in aquatic habitat, and they represent a significant contribution to the food web and in nutrient cycling services. Once the nymphs are mature, they crawl from the water, shed their juvenile exoskeleton and enter the "dun" life stage – they are the ONLY insect order to have a winged stage that is not fully mature, requiring another life stage to reach full maturity. All other insects have completed development once the wings are fully formed. The dun life stage is usually drab in color and does not last long before the mayfly molts into the mature adult, or "spinner". This life stage will reproduce, mate, and females will lay eggs in the water. Many species will not feed as adults, having atrophied mouthparts or guts. Few species have been identified as at least partially parthenogenic. In one peculiar case,the species *Eurylophella oviruptis*, about 60% of the population emerges and follows the typically understood life cycle, mating and lating eggs, but the other 40% of the population are markedly different. This remaining group will reach a mature nymph stage, but instead of emerging the nymphs float to the surface of the water and rupture their abdominal wall, spreading viable eggs across the water.

In application, the Ephemeroptera can be used as Bio-indicators in aquatic habitats, as we examined with the Plecoptera in the first lab. The known tolerances to a range of environmental factors in aquatic systems are well known and can be used to identify potential sites of disturbance, as well as monitor the efficacy of ecological restoration.

Odonata represents two sub-Orders of insects, the **Anisoptera** (the dragonflies) and the **Zygoptera** (the damselflies). These two orders are represented by relatively large insects with elongate wings. They are aerial predators, and thus have evolved excellent visual perception with large compound eyes with smaller, simple ocelli – used for discerning light and dark to orient in flight. The antennae are reduced to short, bristle like protrusions that do not interfere with aerodynamics. Adult damselflies are somewhat smaller and more delicate that dragonflies, especially in the Willamette Valley.

Juveniles for both Odonate orders are aquatic, and predatory in this stage as well. They are large bodied nymphs with large, hinged mouthparts used for ambush predation. Zygoptera nymphs are easily distinguished by the long, fealther-like gills at the terminal end of the insect, while Anisoptera juveniles absorb oxygen from the water using gills held internally in the rectal chambers, pumping their abdomen to increase flow over the structures (figure 2-2).

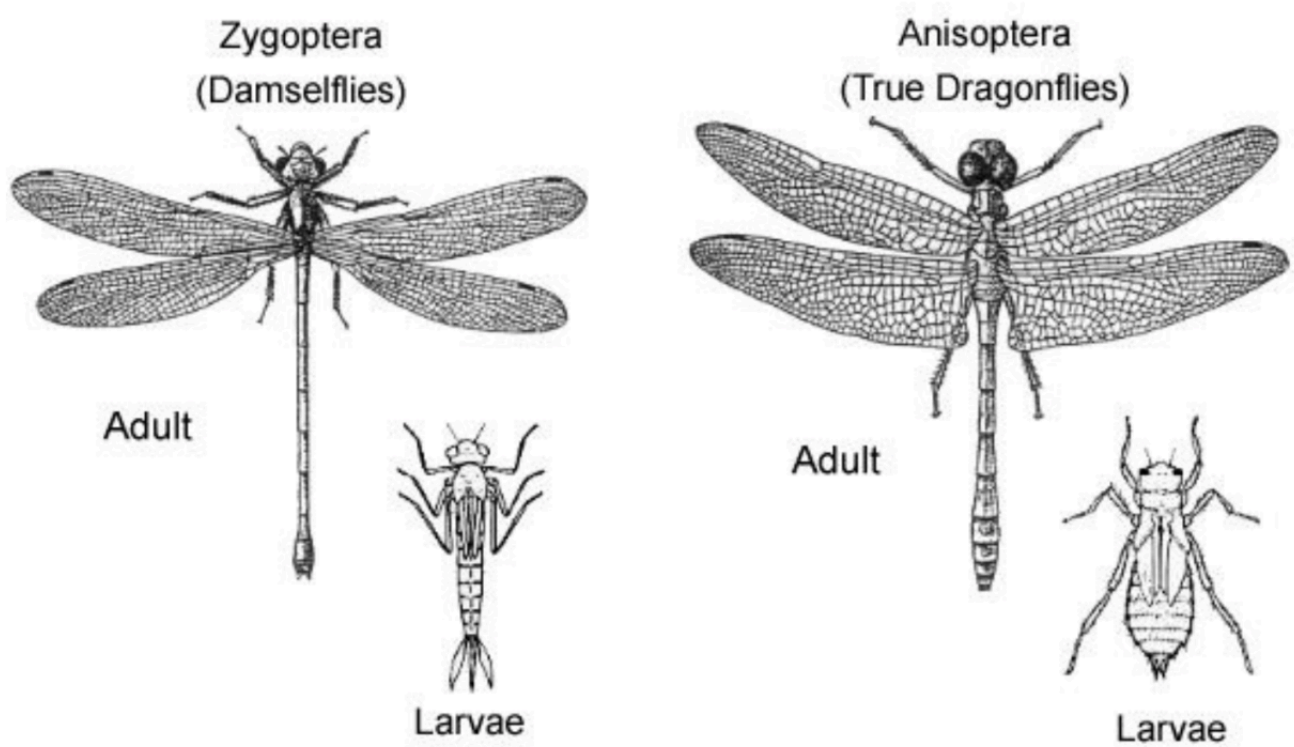


Figure 2-2: *Zygoptera (damselflies) and anisoptera (true dragonflies) can be identified in their larvae state by their gills. Image source: https://projects.ncsu.edu/cals/course/ent425/library/compendium/odonata.html*

Of the **Neoptera,** one of the most primitive orders is the **Blattodea** (cockroaches and termites). Termites may seem very different from cockroaches outwardly, but genetic evidence has revealed how closely related these insects are, even sharing some similar behaviors.

The cockroaches are very simple insects, most well-known for the species that will densely aggregate in urban settings. Adults are alive for the development of their offspring, and familial colonies can become quite large rapidly. Because of the varied food resources exploited by cockroaches, they are reliant on symbiotic gut microbes for digestion. They are not born with the gut microbes required, they must be supplied by the adults in the colony. The cockroaches will engage in *trophallixis*,vomiting into the mouths of the other individuals in the colony to spread the gut microbes. Additionally, the young will eat feces and engage in anal trophallaxis to gain microbe cultures. This behavior is also seen in the termites, which require gut microbes to digest tough woody fibers.

The termites, but comparison, exhibit complex social structure which may have evolved from the close familial colonies in the cockroaches. Termites are primarily underground or in well-sheltered substrate, and are wingless and soft-bodied (unsclerotized) until the time comes for the colony to reproduce. The reproductive "king" and "queen" in the colony will then allow new reproductive to develop, maturing to relative large, sclerotized, winged adults that will leave the colony and disperse to new areas (usually annually in temperate climes). The two pairs of wings, when present, are long and attached to the thorax with flexible bases, making it easy for them to break off once the flighted termites have found a new habitat.

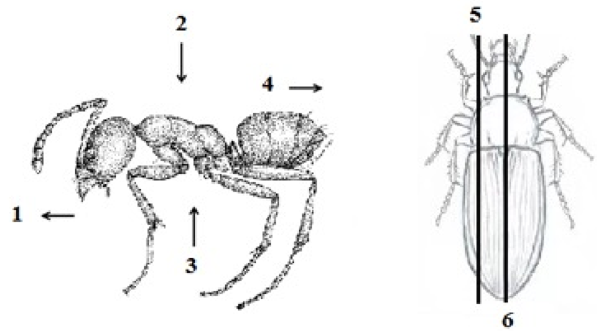
The social structure is known as a "caste system". Each individual termite develops as a pseudergate, or a non-differentiated termite caste, helping with nest work throughout the juvenile stages. The termite will either remain a worker, become a soldier, or even develop into a reproductive. The castes are determined by the presence of oppressive pheromones secreted by the others in each caste. As the older insects die, the relative amounts of their pheromone decreases, allowing more pseudergates to develop into the caste. For example, if the queen dies she can no longer emit Queen Pheromone, which suppresses the sexual development of all other females. The pheromone's level in the colony drops, and female pseudergates begin to sexually mature until a reproductive replacement is in place.

Pre-Lab 2: External Anatomy

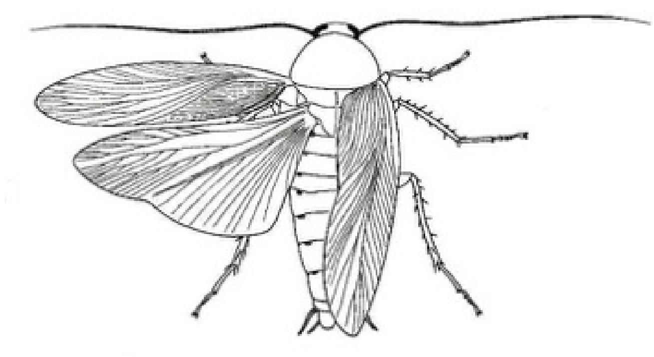
Name: ___________________________________

General Anatomy

Label the body axes on the following diagrams with the most appropriate of the the following terms: **anterior, posterior, dorsal, ventral, medial,** and **lateral.**



External Morphology: On the cockroach below, label the **Antennae, head, T1, T2, T3, Abdomen segments 1 to terminus (9), cerci, legs, forewing, hindwing, lateral margin, anterior, posterior, costal wing margin, jugal lobe, and the prothoracic shield.**



Beyond the general arthropod bauplan, there are many adaptations that allow the organisms to enhance its survival strategy by specific exploitation of habitat conditions, resources or even social interactions. Many of the physiological adaptations are easily seen externally, and allow a viewer to hypothesize ecological roles, life history, etc. Two of the simplest examples are modifications to the antennae and the legs.

What is the function of antennae? ____

Find two examples of modifications to antennae for a specific purpose. In the space provided, draw the antennal structure, give the name for the antennae type, an example of an insect with this antennal type, and describe the need for the adaptation based on the insect life history.

1. Antennal Type: ___________________________________

2. Example Insect: ___________________________________

3. Function: ____

____

____

1. Antennal Type: ___________________________________

2. Example Insect: ___________________________________

3. Function: ____

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Draw (and label) the **Coxa, Trochanter, Femur, Tibia, Tarsus,** and **Pre-Tarsus (claw)** leg segments on an unmodified, typical insect leg (i.e. a cockroach or grasshopper foreleg).

As with the antennae above, find two examples of modifications to leg structures for a specific purpose. In the space provided on the next page, draw the leg structure for each, naming for the leg type and showing the segment modified, then give an example of an insect with this leg type, and describe the need for the adaptation based on the insect life history.

1. Leg Type/Segment Modified: _________________________

2. Example Insect: ___________________________________

3. Function: ____

____

____

1. Leg Type/Segment Modified: _________________________

2. Example Insect: ___________________________________

3. Function: ____

____

____

Lab 2 Assignment: Internal Anatomy

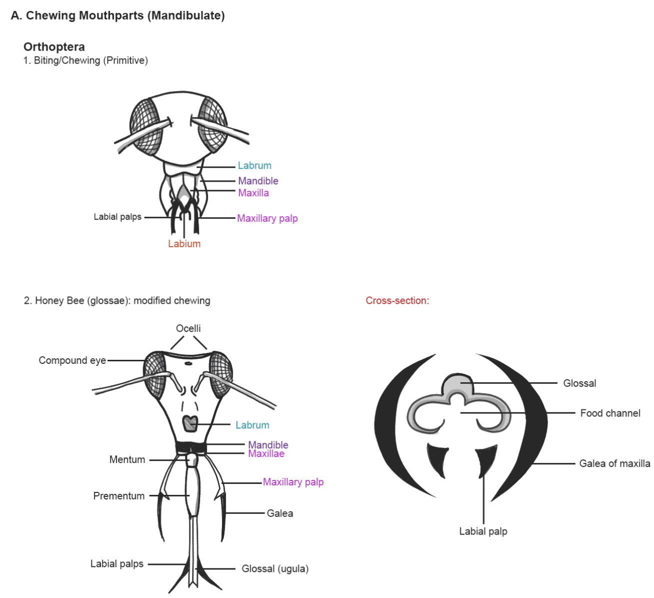
Name: ___________________________________

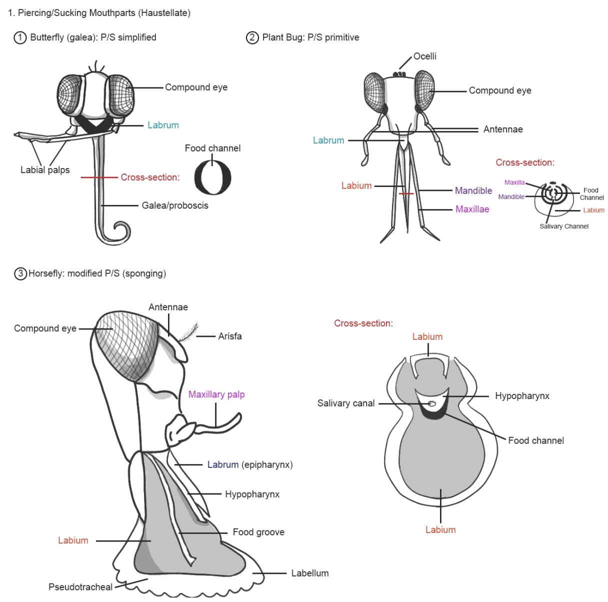
I. Closely examine the HEAD of your cockroach. As best as you can, draw the face, noting the **Compound eyes, ocelli, antennal scales, hairs,** and **mouthparts.**

What is the difference between the ocelli and the compound eyes? When might an insect have ocelli, but not compound eyes? What kinds of insects need both? Why?

Mouthparts

There are two main kinds of arthropod mouthparts: mandibulate (chewing) and haustellate (piercing/sucking; insects only). They are both made of the same basic components, but can be highly modified to exploit a variety of food resources. In the diagram to the right, **draw a circle around the insects with haustellate mouthparts.**





Dissection

Looking closely at your specimen, not there is a thin, flexible plate-like sclerite (scale) that extends above the mouthparts like an upper lip. This is the **labrum.** The role of the labrum is to contain the food in the oral cavity while the mandibles and maxilla shred the food item. Gripping the head of the cockroach firmly, gently lift the labrum with a pair of dissection scissors and cut it from the front (the frontal plate of the head) as close to the attachment point as possible.

Below the labrum are two large, durable **mandibles**. They will be large enough to cover all the underlying mouth parts, their size an indication of their importance for crushing, tearing and grinding food. They open from side to side, not up and down. They are tough, rigid structures and will be difficult to open and remove to see the maxillae beneath. Using a pair of rigid forceps, grip one mandible and pull gently to open and separate it from the other. Wiggling the mandible gently from side to side, remove it, tearing through the muscle attachments.

Once the mandibles are removed or opened, the other pair of mouthparts that will be evident are the **maxillae**. The maxillae also meet on a vertical axis, but have only one dark sclerotic projection while the mandibles have an entire margin of dark, serrated teeth. The mandibles also have a pair of long, finger-like palps projecting from the outside margin. These palps assist in shoving food into the alimentary canal as the insect feeds. Grip one maxillae gently from the base (do NOT pull on the palp) to remove.

The remaining mouthpart hanging down should be the **labium,** or “lower lip” as it is sometimes called. This is the floor of the oral cavity, the right and left parts fused into one with a pair of labial palps projecting forward. Grip the labium from the base and pull to remove.

5. Following removal of all previous mouthparts, a fleshy, tongue-like projection can be seen protruding from the alimentary canal. This is the **hypopharynx**, the structure involved with taste perception, and more importantly with suction. In haustellate insects, the hypopharynx is well-developed and responsible for withdrawing fluid from the host for consumption.

Draw (and label) the individual parts, the **labrum, mandible, maxillae (with palp), hypopharynx** and **labium (with palp)** below.

Examine the mouthpart modifications diagram on the next page. In the upper left corner, you should recognize mandibulate mouthparts from the dissection you completed. Moving right are examples of honey bee mouthparts, also mandibulate but with a modified "glossae" which operates as a long tongue.

In the second row, the haustellate mouthparts of a mosquito are shown on the left, and a cross section of the proboscis on the right. In haustellate insects, the same mouthpart components are present, though elongated and modified into bristles. These bristles are pressed together to form a stylet, a structure with separate channels for injection of saliva (salivary groove) and removal of food item (food channel). Note the size of the hypopharynx in the examples of haustellate mouthparts – this is the organ responsible for drawing the fluid out of the host and up through the food canal.

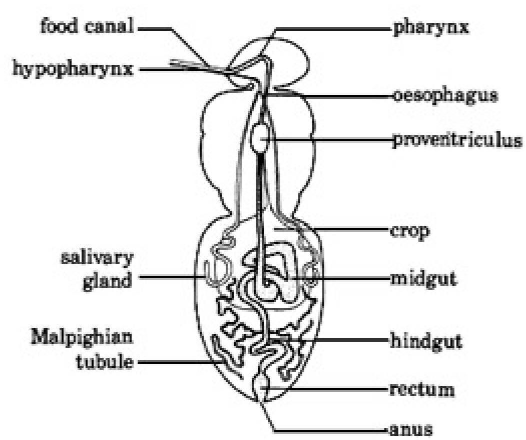
The mosquito is a primitive example of haustellate mouthparts; from there, oral modifications become even more specified to food resource by fusing structures to create new appendages (the labellular organ of a house fly) or reducing/losing structures completely (the simple proboscis of a butterfly).

What is the function of the labellum and pseudotracheae (housefly)?

In many holometabolous (we'll get into this next week) insects – insects with a pupal stage – the larvae frequently have different mouthparts than the mature adults. Why do you suppose this has occurred? (Example: mandibulate caterpillar, haustellate butterfly/moth)

Internal Organ Systems of the Insects

Digestive System



The digestive system of insects is composed of the mouth parts and the alimentary canal, both of which can be specialized in structure and function to correlate with specific diets. When the food supply of a particular insect group is readily available (such as insects that feed on plant parts), the gut is usually short and without storage capacity. However, if an insect is predacious, the gut is modified for storage to compensate for the long time periods a predator may go without a prey item.

There are three main regions of the alimentary canal: the foregut, the midgut, and the hindgut. Each section is separated from the other by valves which control the movement of food between regions. The foregut functions to ingest, store (crop) and grind (Proventriculus) the food before it is passed to the midgut. The majority of digestive enzyme production occurs in the midgut region (from the gastric cacao and midgut wall), as does the absorption of the products of digestion (proteins, carbohydrates, minerals, salts, water, lipids). The hindgut functions in final absorption of salts and water prior to the elimination of the feces through the anus.

The exoskeleton lines the foregut and the hindgut and thus is shed with each ecdysis event. The midgut is the only section with a lining that is not shed.

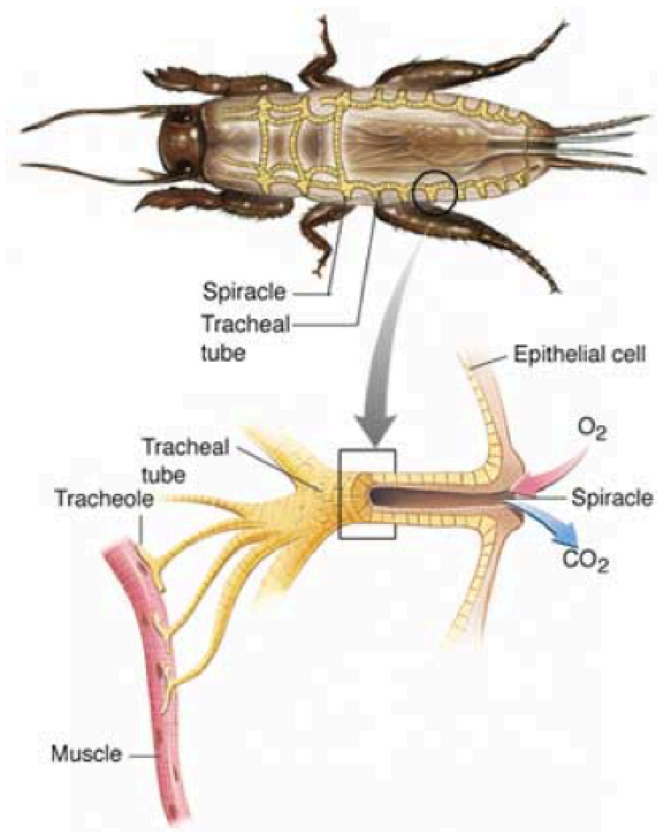
Excretory System

Insects eliminate wastes in a variety of ways they often absorb some waste products in specialized cells alongside the heart. These cells are called pericardial cells and this form of excretion is termed storage excretion. Other cells and organs may be involved in storage excretion. For example, the fat body and certain reproductive organs may store massive amounts of uric acid (one of the main waste products protein metabolism) and thus often appears in varying shades of yellow depending on concentration.

The primary urinary vessels in insects are the Malpighian tubules. These tubes empty into the pylorus. They vary in number from very few to hundreds depending upon the insect. One part of the tubule often absorbs water and salts from the hemolymph and some of these are again reabsorbed at another part of the same tubule. Urine flow in insects is controlled by potassium ions; then the amount of this salt is high, there is an increase in urine flow. Then the amount of potassium, urine flow ceases. Uric acid is often excreted by way of the Malpighian tubules.

Respiratory System

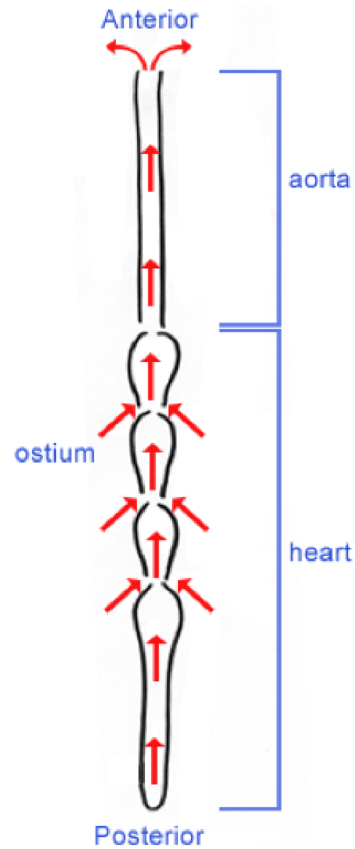
Most insects breathe through a system of special branching tubes called tracheae. The openings into these tracheal tubes are along the body wall, usually at the lateral margin, and are called spiracles. Spiracles play a role in water retention, and are therefore usually kept tightly closed. Tracheal tubes are lined with a fine, tightly-wound spiral of chitin called the taenidia. The taenidia acts to strengthen the tracheal tubes against collapse while still allowing the tubes to be flexible. As the tracheal tubes approach an organ, they tend to get finer. The finest tracheal branches are termed tracheoles.



In insects where the tracheae open to the exterior via the spiracles, respiration is said to occur through an open tracheal system. However, in some insects and insect larvae, spiracles are absent. In this case, the tracheae form a subcutaneous network that covers the body surface. In this case, gas exchange occurs directly through the integument in what is termed a closed tracheal system. The trachea lead directly into the muscle cells, providing direct oxygenation without using blood or capillary transfer.

Circulatory System

Insects have an open circulatory system. A dorsal blood vessel serves as the main as the main blood vessel in insects. Outside of this dorsal vessel, the blood circulates freely within the insect body cavity. The posterior (rear) portion of the vessel, which is known as the heart, is subdivide into a series of chambers, each with an ostia through which blood may enter. The anterior (front) portion of the dorsal blood vessel is known as the aorta. Rather than pumping to circulate blood, the dorsal vessel uses a peristaltic wave, much like swallowing in humans, to create a current of flow in the body of the insect. There may be additional accessory pumping organs in some insects to prevent pooling – for example, in the insect foot or base of the wings.

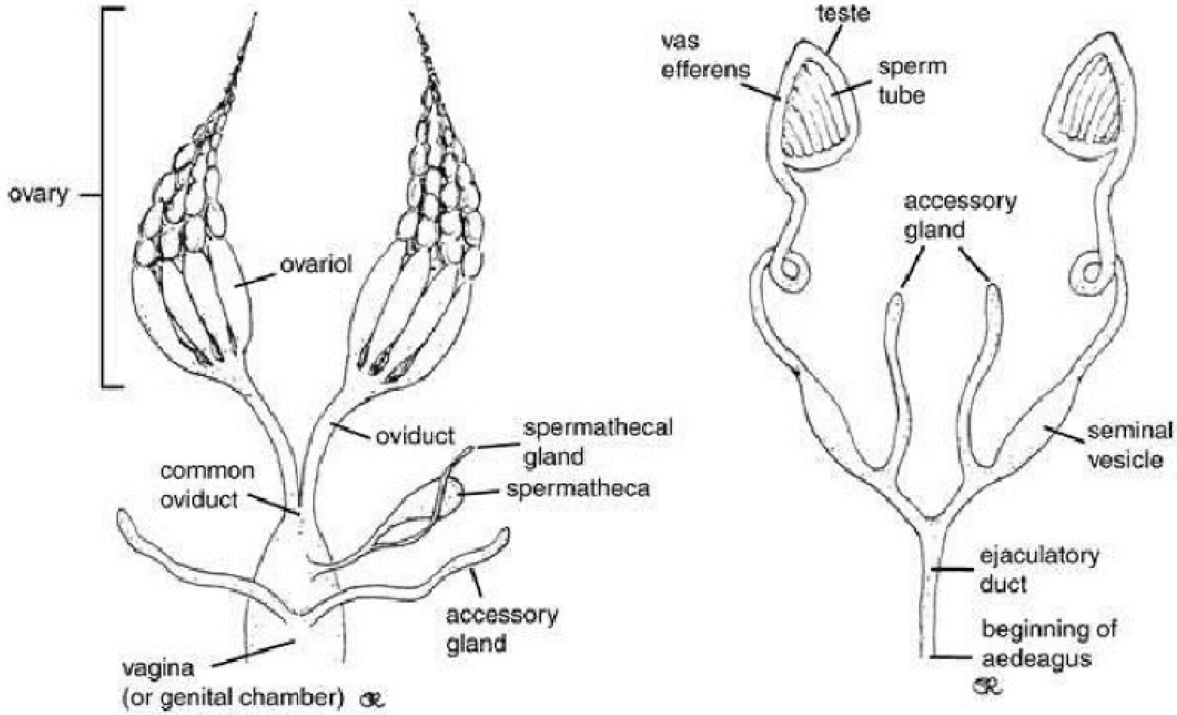


Because it differs so much from the circulatory fluid of humans, the "blood" of an insect is called hemolymph. The hemolymph of insects transports nutrients, hormones, and waste products. The cells which circulate in the hemolymph are called hemocytes. Hemocytes vary in size, shape, and function. Some hemoctyes are capable of phagocytosis and encapsulation, while others function in coagulation and wound healing.

Reproductive System

The internal reproductive system of female insects consists of pair of ovaries, the lateral and median oviducts (through which the eggs pass to the outside), a spermatheca (which stores sperm until they are needed for fertilization), a genital chamber (which is where fertilization generally occurs), and the accessory glands. Each ovary consists of a cluster of ovarian tubes, known as the ovarioles. The ovarioles contain a series of developing eggs, which will be passed into the lateral oviduct upon maturation.

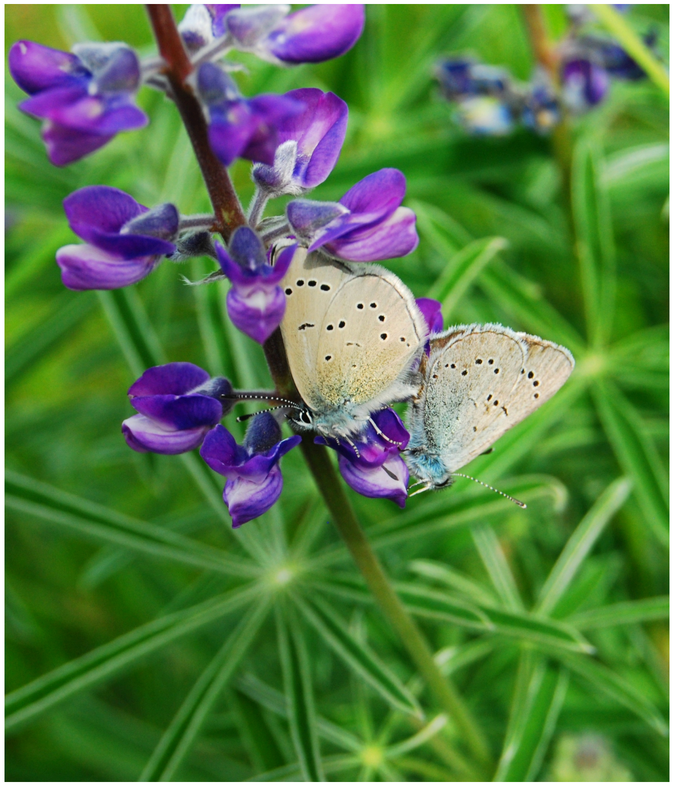
The male reproductive system consists of a pair of testes, each of which contained a series of sperm tubes in which the spermatozoa are produced. Mature sperm are passed through the seminal vesicles, and out of the insect through the ejaculatory duct. The paired accessory glands may serve a variety of functions in male insects. Secretions from these gland may surround the spermatozoa to form a spermatophore or may nourish the spermatozoa during sperm transport into the female.



Female reproductive tract (left) and male reproductive tract (right)

Internal Anatomy: Carefully cut through the exoskeleton as instructed. DRAW the internal structures on the following page. Label the **esophagus, salivary gland, crop, proventriculus (gizzard), gastric (hepatic) caeca, foregut, mesenteron (midgut), intestine (ilium), colon (hindgut), trachea, anal cercus,** and **Malpighian tubules**.

WEEK 3: COLEOPTERA AND LEPIDOPTERA



Week 3 Materials

Reading

Week 3: Reading ..... [WEB]

Pre-lab 3 Download

Pre-lab 3 .... [WEB][PDF][WORD]

Lab 3 Download

Lab 3 Assignment ... [WEB][PDF][WORD]

Week 3: Reading

Coleoptera & Lepidoptera

Figure 3-1: *Larvae of the ponderous or prions borer, a root borer. Image source: https://commons.wikimedia.org/w/index.php?title=File:1935._The_ponderous_borer._Cerambycidae._Ergates_spiculatus_larvae._(26445184219).jpg&oldid=302453315*

The **Coleoptera** are one of the most primitive insects of the Neoptera, and are characterized by the hardened forewings appearing as a hard shell, the **elytra,** protecting the membranous wings (used for flight) beneath (Coleo = sheath; ptera = wings). This group includes the beetles and weevils, which are often confused with members of Hemiptera. A few key characteristics separate the initial appearance of these two orders: 1) the Hemiptera have only piercing/sucking mouthparts and Coleoptera have only chewing mouthparts (in all stages); 2) the wings of the Heteroptera cross over each other on the dorsum of the insect, and the elytra of the Coleoptera met medially on the dorsum creating a visible suture down the dorsal medial line of the abdomen.

There are over 350,000 known beetle species, and until recently was consider the most abundant of the insect orders (replaced recently by the Hymenoptera). They are holometabolous, with a larvae frequently referred to as "grubs". Some of the species in Oregon are quite large and long-lived in the larval stage: the family Cerambycidae – the long-horned beetles – have representative detritivore species with larval stages that can last 2-5 years and grow several inches in length as mature larvae (figure 3-1).

Figure 3-2: *The Rosalia Beetle, which lives out its entire life cycle on decaying wood. Image source: https://en.wikipedia.org/wiki/File:Rosalia_funebris_resting.jpg*

Beetles are found in almost every known habitat and take advantage of a wide range of resources. The first insects to develop pollination symbioses with Angiosperms were beetles first feeding on the fleshy petals of the first flowering plants. The beetles are abundant on vegetation, feeding on all parts of the plants in different life stages, and the Rosalia Beetle (figure 3-1) completes its life cycle completely on dead and decaying wood. Many beetles behave as pests in production systems, feeding on all parts of a wide variety of plants. For example, the weevils belong to the family Curculionidae, and are identified generally by the extended rostrom (figure 3-3). Weevil larvae live in the soil and feed on the roots of many different kinds of plants, causing damage to newly established plants and seedlings. The adults are foliage feeders above the soil line and can cause significant damage to plant tissues.

There are many beetle species that are generalists, such as the Black Vine Weevil, but there are also many specialists (figure 3-4). The Carrion Beetle (Family Silphidae; image right) requires carrion to complete its lifecycle, and as a result is specialized to find and feed on decaying animals, often locating food at a distance of several miles. The lamellate antennae provide a broad surface area for enhanced chemoreception, making this specialism possible. Other specialist feed on fungi or are parasitic, and there are several species with aquatic life stages (either the larvae only or both the larvae and adults).

Figure 3-3: *Weevils belong to the family Curculionidae and are identified by their extended rostrum as seen in this Radish Seed Weevil. Image source: https://commons.wikimedia.org/w/index.php?title=File:Cabbage_Seedpod_Weevil_-_Ceutorhynchus_obstrictus_(22876817109).jpg&oldid=228311769*

In addition to pest species, there are also predatory beetles the can provide pest suppression in production systems. Predatory Ground Beetles (Family Carabidae, figure 3-5) are active at night, searching the ground for other nocturnal arthropods. There are many species found in Oregon, and they are easily captured and monitored using pit fall traps left over night (dry; these are beneficial insects desired alive). Some are quite large, and some species have impressive mandibles for crushing and consuming prey. During the day they are typically hidden under stones and bark, compost and other sheltered locations.

The **Lepidoptera** include the moths and butterflies and are named for the scales that make up the coloration pattern on the wings (Lepido = scale, ptera = wing). All of the Lepidoptera are holometabolous, though in this case the mouthparts are different between the larval and adult stages. Caterpillars are equipped with chewing mouthparts, and have large modified salivary glands that can produce silk, and adult butterflies and moths have piercing/sucking mouthparts, generally called the "proboscis" (figure 3-6).

Figure 3-4: *The Black Vine Weevil is considered to be a generalist. Image source: https://www.flickr.com/photos/14583963@N00/5771039710*

Figure 3-5: *The Ground Beetle, Genus Pterostichus, are active at night and search the ground for arthropods. Image source: https://www.flickr.com/photos/pcoin/4633697299*

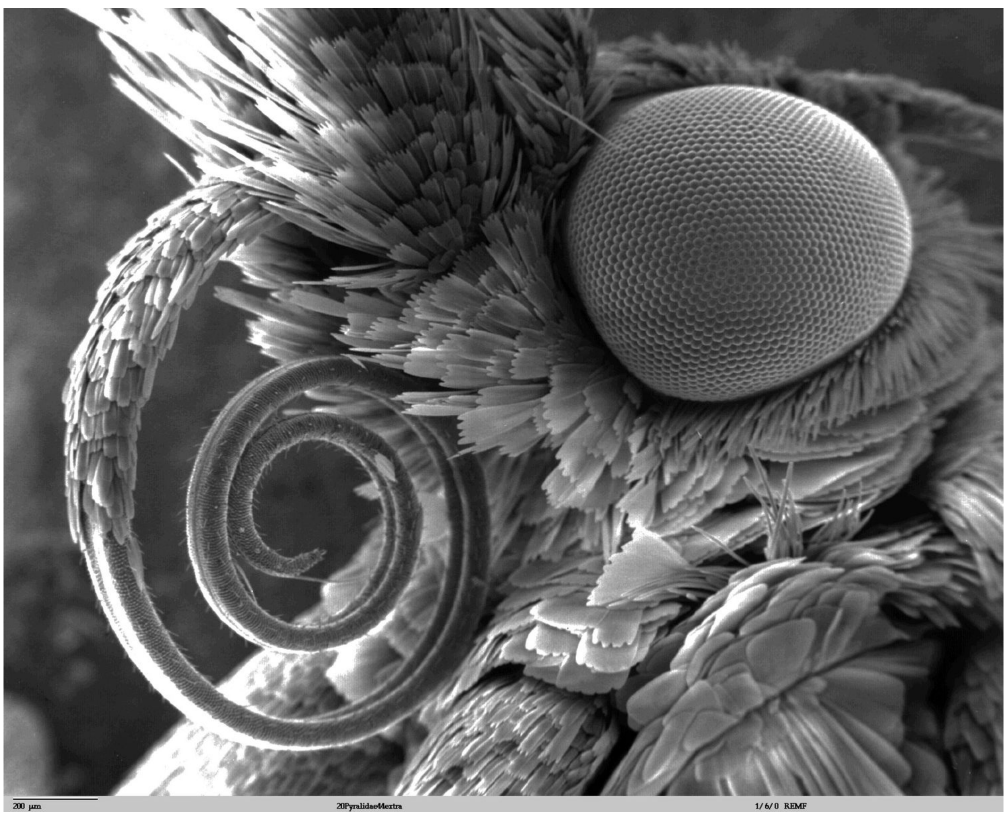


Figure 3-6: *SEM image of Lepidoptera Proboscis found on moths and butterflies. Image source: https://commons.wikimedia.org/w/index.php?title=File:Gemeiner_Totengr%C3%A4ber_(Nicrophorus_vespillo)_(14752225310).jpg&oldid=315651391*

Recent genetic studies have shown that there is no indication of a true divergence separating the moths (Sub-Order Heterocera)from the butterflies (Sub-Order Rhopalocera), and indeed some species of moths are more closely related to species considered butterflies than they are to species considered moths. That said, the difference between these two groups is an artificial separation that may be attributed to behaviors: in general, moths are night-flying and are generally more cryptic in their habitat, while butterflies fly during the day and rely less on camouflage for predator evasion.

There are over 150,000 species known in the Lepidoptera. Identifying this order is relatively easy, as only one other Order has flighted insects with scales on the wings, the Trichoptera, and the adults of the Trichoptera are distinguished by their chewing mouthparts. Lepidoptera have two pairs of scaled wings, the forewings obviously larger than the hind wings. Body size is extremely variable, ranging from the 4 mm micro-moths to the 100 mm charismatic macrofauna that make the Lepidoptera a common favorite with hobbyists. The body and legs are also usually covered with scales, and the labial palps are almost always well-developed and obvious, held extended in front of the insect head.

The larvae of the Lepidoptera are frequently the most relevant to agricultural production, as many behave as pests and consume a wide range of host plants. However, many of these species will be targeted by wasp and fly parasitoids naturally. Identification of larvae to family can be difficult, but there are a few local resources that will be very helpful:

http://pnwmoths.biol.wwu.edu/

https://www.fs.fed.us/foresthealth/technology/pdfs/FHTET_03_11.pdf

https://cfs.nrcan.gc.ca/publications?id=26133 (This resource will help separate caterpillars from other grub-like larvae in other orders)

Pre-Lab 3: Insect Development

Name: ________________________________

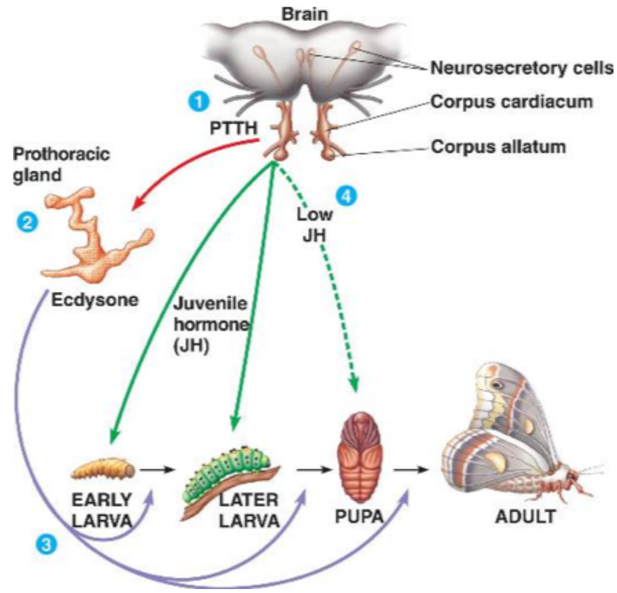
The rigid exoskeleton, also called the "cuticle", of insects enables them to do many things, but is an obstacle to growth. In order to grow, an insect must periodically shed its exoskeleton and grow a new one that is larger. The process whereby a new cuticle is formed and the old one is shed is called molting. Molting is a complex process which is controlled by hormones.

Insect Cuticle: Draw the layers of the insect cuticle, labeling the following components: **epidermis, endocuticle, exocuticle, inner epicuticle, outer epicuticle, wax layer** and **cement layer.**

During insect growth and molting, each successive stage may appear similar to the preceding stage, or the appearance may change from stage to stage. This change in form from molt to molt is called **metamorphosis**. There are four types of metamorphosis:

- Ametaboly — No marked change in form between a newly hatched nymph and the adult. The adult differs from the nymph only in size and in having reproductive structures. (Ex. Collembola)
- Paurometaboly — The nymph does not closely resemble the adult because it lives in the water, breathes through gills, and has gradually enlarging external wings. (Ex. Odonata)
- Hemimetaboly — The nymph resembles the adult, except in size and the absence of wings and reproductive structures. Wing buds develop externally. (Ex. Orthoptera)
- Holometaboly — The larva does not resemble the adult form and frequently differs in feeding habits and habitat (where it lives). There is a pupal stage intermediate between the last larval stage and the adult. Wing development is internal.

As the insect develops, an interaction between three hormones regulates development in time with ecdysis events in response to environmental and physiological cues.



When the brain receives the appropriate cue, which may be soil temperature for an overwintering insect, day length, or any number of factors, it causes the brain to release **Prothoracicotropic Hormone**, also called PTTH or simply "brain hormone". PTTH acts on the *prothoracic gland*(hence the long name), stimulating the gland to release the hormone **Ecdysone**. When released, ecdysone triggers an ecdysis event.

The final hormone in the interaction regulates the degree of maturity of the stages between ecdysis events, called "instars". Juveniles and larvae may go through several immature instars, molting between each and maturing slightly with each stage before becoming a mature adult. As they develop, a special section of the brain called the *corpus allatum* secretes **Juvenile Hormone,** known simply as "JH". The more JH present in the insect, the more immature the tissues remain. JH levels are high in early instar immature insects, and tapers off as the insect matures: less Juvenile Hormone means a less juvenile insect. Juvenile Hormone is in the lowest concentration in the last stage of immaturity: the last juvenile instar or the pupal stage for holometabolous insects. The absence of juvenile hormone at the last ecdysis event allows mature adult tissues to form, including functional wings and mature reproductive systems.

There are a few further conditions that may vary development. Define the following, and give an insect example.

1. Diapause

2. Hypermetabola

3. Sub-imago

The more recently derived (evolved) insect orders are the holometabolous orders, while ametabola, then hemi- and paurometabola are considered more primitive conditions. With the energetic expenditure of metamorphosis and the extended time spent in a vulnerable pupal stage, why do you supposed was favored as a life history strategy and preserved evolutionarily? What are the benefits or reasons for metamorphosis? Defend your answer.

Lab 3 Assignment: Degree Day Models

Name: ___________________________________

Apple codling moth (*Cydia pomonella*) is a major pest of apples and pears in the Pacific Northwest. If left unchecked, complete crop loss is likely. Research on the biology and development of codling moth in different climes has advanced management practices for growers. The websites and tools used in this exercise are the tools used by apple and pear growers to time pest management to be most effective with the least amount of non-target impact on beneficial predators and the environment.

Instructions: Use the websites listed to answer questions about the biology and development of the codling moth.

Part I. Biology

WSU codling moth website: http://jenny.tfrec.wsu.edu/opm/displayspecies.php?pn=5 (inactive link as of 05/24/2021)

1. What are the four life stages of codling moth? Describe each.

2. In which stage does the codling moth overwinter in the Pacific Northwest?

3. How long does it take for newly emerged female adults to begin laying eggs?

4. How many days does it take for egg hatch/larval emergence?

5. In general, how long will the larvae be in the **feeding** stage?

6. How many generations per year are typical in Oregon **in a warm year vs. a cold year**?

7. Which life stage is most susceptible to control with pesticides? Why?

Part II. Using a Degree Day Model – Regional Comparison

Apples are grown in many regions of the United States. Two major growing areas in the Pacific Northwest are Milton-Freewater (north of Pendleton) and Medford (southern Oregon). Use the links below to answer the following questions:

WSU codling moth website: http://jenny.tfrec.wsu.edu/opm/displayspecies.php?pn=5 (inactive link as of 05/24/2021)

OSU IPPC Degree Day Model website: http://uspest.org/cgi-bin/ddmodel.us

1. What does the term "biofix" mean, with regard to degree day models in general?

2. What is the upper and lower developmental threshold for apple codling moth? What does this mean (at either end?)

3. What is a pheromone trap, and how are they used to manage codling moth?

Management Strategies

In Washington and Oregon, what stage of development for the codling moth should applications of insecticides be made to the orchards for reliable control at a susceptible life stage? How many degree days have accumulated at time of most effective spray?

a. First generation:

b. Second generation:

Degree-day Calculations: Milton-Freewater

Using the IPPC website, calculate the degree day model for January 1 – August 31 of last year, using model "Codling Moth WSU revised 06 (Knight)". Select a weather station in Milton Freewater and record the station Identification Number/Name here: ________________________.

Press "Calc/Run".

Open a second tab and do the same for a weather station in Medford, Oregon. Record the station Identification number/Name here: _____________________________.

Fill in the table of comparison on the following page and answer the questions.

Station ID: M-F: _______________________ Medford: ______________________

Date of estimated first catch:		
Critical Date Range for 1st generation spray:		
Critical Date range for 2nd generation spray:		

4. What would be the difficulty in managing codling moth if growers did not have knowledge of moth phenology?

5. How does degree-day model information change decision-making in pest management for the benefit of the grower?

WEEK 4: ORTHOPTEROID ORDERS

Week 4 Materials

Reading

Week 4: Reading ..... [WEB]

Pre-lab 4 Download

Pre-lab 4 .... [WEB][PDF][WORD]

Lab 4 Download

Lab 4 Assignment ... [WEB][PDF][WORD]

Week 4: Reading

Orthopteroid Orders

The **Orthopteroid Orders** is a general grouping of the more primitive neoptera groups that share characteristics similar to the order containing the grasshoppers, crickets and katydids, the Orthoptera. These orders are paurometabolous, meaning they complete development in successional stages with no pupal stage; sexual development and adult tissue development advances with each molting event until the insect has reached full maturity (for winged members, the wings are fully developed). All members of this group have chewing mouthparts, and many species have massive mandibles and maxilla. All members of this group are phytophygous except the Dermaptera (earwigs).

Figure 4-1: *Hatching Mantid ootheca. Image source: https://www.flickr.com/photos/grahamenz/2120451737*

Usually for the Orthopteroids, eggs are laid in clutches, grouped together and held with some kind of material from the mother ranging from a wet, slightly viscous mucous to a toughed, styrofoam-like case. However, there are members of the Orthopteroids that do not do this – for example, stick insects (Order Phasmatodea) lay eggs one at a time, dropping them to the ground as they are produced (figure 4-1).

The Orthopteroid Orders

The Orthopteroid Orders include the extant orders of the Paleoptera, and the Blattodea/Isoptera Orders examined in Week 2 reading.

The **Orthoptera** are considered "primitive" because of the paurometabolous life cycle and the simplified body plan. They are relatively large insects in general, with two pairs of wings when present (several species have secondarily lost wing structures). The forewing is thicker in texture, parchment-like, and is referred to as the "tegmina". This is a common term in other orders with similarly thickened wings. The wings may also be modified to create sound, and the calls of the Orthoptera will be specific to species and reason for the call: defense, mating calls, territorial calls, etc. In addition to the wings and sound production, the true Orthoptera can also be identified by the enlarged hind femora, modified for jumping (a saltatorial leg structure; figure 4-2).

Figure 4-2: *Orthoptera, identified by the enlarged hind femora, modified for jumping. Image source: https://www.maxpixel.net/Insect-Grasshoppers-Flight-Insect-Orthoptera-2289708*

Orthoptera are most often noticed in crop and production systems because of the rapid amount of destruction caused with large, chewing mouthparts. Within the order, however, there are only a few families that will become problem pests (like the Short-horned Grasshoppers in the family Acrididae), mostly because they will be multi-generational in the same season. Adult females will use the large, obvious ovipositors (figure 4-3) to dig holes at the base of host plants, depositing eggs into the hole where the newly-hatched offspring will have ready access to food.

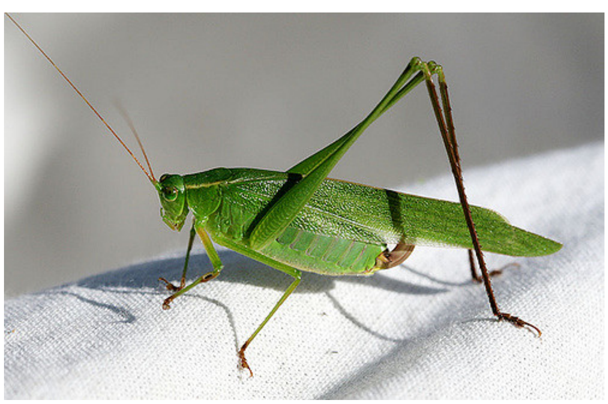


Figure 4-3: *Female Tettigoniidae (Katydid) with obvious ovipositor. Image source: https://www.flickr.com/photos/pcoin/1490416130/*

Figure 4-4: *Phasmatedea which includes walking sticks and leaf bugs, including one species of stick bug in reported in Oregon, the Northern Stick Bug. Image source: https://commons.wikimedia.org/w/index.php?title=File:Stick_Insect_(Phasmatodea)_(15091394153).jpg&oldid=281913735*

Stoneflies, order **Plecoptera**, are also considered Orthopteroid, but have little importance to production systems. Though they are important contributors to aquatic and riverine trophic systems, they do not feed on crops or cause damage. Occasionally they will feed on pollen to gain sufficient protein for mating, but they do not feed with high enough intensity to be considered pollinators.

The **Phasmatodea** includes the walking sticks and leaf bugs. There is one species of stick bug, the Northern Stick Bug, that has been reported in Oregon but sightings are extremely rare (figure 4-4). Other species of this Order have been restricted for transport as pets or for husbandry in the last few years due to their ability to feed heavily on members of the Roseaceae family, particularly within the genus *Rubus*. These insects are a potential invasive pest due, especially since many of the females are parthenogenic, producing viable eggs without male fertilization, allowing colonies to grow rapidly.

The order **Dermaptera** is more commonly referred to as the "Earwig" order, and there is only one family in Oregon: Forficulidae, the family for the invasive European Earwig. The tegmina of the earwig is extremely short, covering only a few of the most anterior abdominal segments leaving the rest exposed dorsally. The hindwings are surprisingly large, and are folded fan-like beneath the tegmina when not in use. Another readily assessed characteristic of this group are the large, forcep-like terminal appendages. Males will use these to fight and remove other, competing males when there is a female present. The shape of these appendages make it easy to distinguish male from female: a recurved inner margin indicates male, while a relatively straight inner margin indicates female (figure 4-5).

Figure 4-5: *Order Dermaptera, or commonly referred to as the "Earwig." Image source: https://commons.wikimedia.org/w/index.php?title=File:Dermaptera_(Earwig)_7718.jpg&oldid=327190826*

The Dermaptera are cosmetic pests: not only can they be startling, but they may defecate on the surface of fruit and flowers of ornamental plants. However, these insects are not necessarily economically damaging, as this is the only Orthopteroid group that may predate on other pests present.

Pre-Lab 4: Pest Monitering

Name: ___________________________________

Basic overview of IPM Programs and benefits, UC IPM: http://www2.ipm.ucanr.edu/WhatIsIPM/

Monitoring insects involves many techniques and methods for observing and measuring population growth, changes, damage to hosts, and other relevant activities over long periods of time, in response to changing environmental factors. From the options below, check the boxes that can be benefits of utilizing a well-planned monitoring schedule:

- □ Develop a historical record of pest outbreaks and beneficial insect presence for use in decision-making
- □ Help to identify potential future outbreaks, non-target impacts, and resurgence events
- □ Justify pest management recommendations to farm managers, owners or clients of pest management consultants
- □ Provide information to simplify future monitoring efforts
- □ Provide feedback about pest management program efficacy
- □ Determine economic cost/benefit of a pest management recommendation to avoid unnecessary pest control treatment and expenditure while avoiding crop losses

When monitoring a field crop site for pest damage, there are many non-insect/arthropod observations that should be made. Michigan State Extention has created a brief, helpful guide to monitoring pests in field crops: http://msue.anr.msu.edu/resources/pest_scouting_in_field_crops_e3294

Give an example of THREE **field observations** (IN ADDITION to the pest data) that should be made each time field monitoring events occur, explaining why each is important to note.

Understanding basic population dynamics is important for monitoring pest populations: this can include isolating specific demographies, tracking the relationship between population size and population density on-site, and understand the way these metrics change with time. Here is a link to a good primer on population biology: https://courses.lumenlearning.com/boundless-biology/chapter/population-demography/

When sampling for pest presence or damage, it is impossible to completely check ALL potential host plants. As a result, field agents rely on sampling units that will minimize time and effort. Types of sample units vary from square-meter area monitoring to a single plant per area, or even a certain number of leaves per plant depending on the needs of the study, the host plant, or pest pressure thresholds. Identifying the appropriate sampling unit and number of samples is vital for understanding the way pest insects are interacting with the crop. For example, misunderstanding the typical distribution pattern of a pest in a space may cause populations of the pest to be overestimated (resulting in unnecessary expenditure in control methods) or underestimated (resulting in crop loss).

There are three main distribution pattern types: clumped, random and uniform. Research these distribution patterns and describe each, drawing an example for each in the space to the right of each.

UNIFORM:

RANDOM:

CLUMPED:

What important biological information can a grower or researcher learn about pests by examining distribution patterns?

Lab Assignment 4: Population Monitoring and Field Sampling

Name: ___________________________________

Sampling for pests only provides useful estimates of population size when two important aspects are addressed: **accuracy** and **precision**. Accuracy is how close your sampling is able to reflect actual population size. Precision is when the data collected in each sampling event are relatively equal, with little or no variation. When precision is poor, more samples are required to generate more accurate data.

Determining sample size: Rarefaction Curves

With each sampling event, we gain more information about our ecosystem. In the example below, you'll be filling in Table 1 with the values given using Appendix A, which is a data set built on number of insects recorded during scouting.

Sample No.	# Species in Sample	Total NEW Species	TOTAL SPECIES **(Cumulative)**
1			
2			
3			
4			
5			

Table 1.

Using your data, extrapolate the results to reflect a hypothetical organic garden that when considered as a whole, is comprised of 150 plots of the same size.

For example:

- If there were a total of 40 individuals sampled, and 10 are pest species A, then species A is 25% of the population (10/40 = .25). This percentage is the **relative abundance.**
- 25% of 150 (150×25) is 37.5, so we assume that in the entire production area, there should be about 38 (rounding to the whole insect) species A individuals.

Species No.	Species Name	Total No. Sampled **(cumulative)**	Relative Abundance (%)	Extrapolated Abundance (x30)

Table 2.

Now add the data from the next 5 samples (samples 6-10), adding to your counts, in the table below.

Sample No.	# Species in Sample	Total NEW Species **(including prev. samples)**	Total **Cumulative** Species
6			
7			
8			
9			
10			

Table 3.

With the new data, you'll need to recalculate the relative and total abundance for each species identified over 10 sampling events.

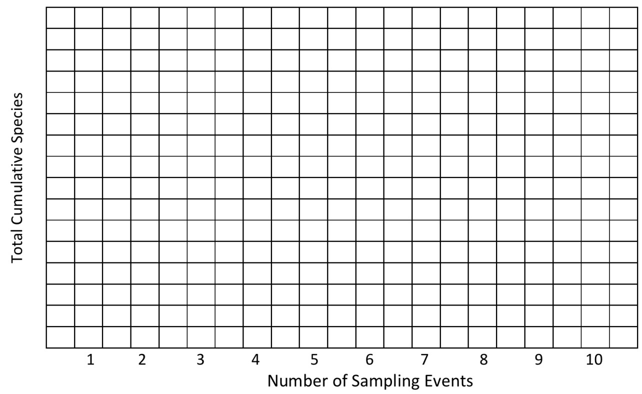
Species No.	Species Name	Total No. Sampled **(cumulative)**	Relative Abundance (%)	Extrapolated Abundance (x15)

Table 4.

Was there a difference in the number of the species between table 1 and table 3? Is the changing number of species an indication of changing accuracy or precision?

Was there a difference in the overall relative abundances for each species? Why/Why not?

Plot your data on the graph below, showing the total number of species found as a response to the number of samples taken by highlighting the cells in the table at each data point. Because we are tracking cumulative data, connect the data points with a line of highlighted cells



The plot you have just created above is what is known as a **rarefaction curve.** This helps consultants and scientists monitoring populations of organisms select the correct sampling effort (number of sampling events or number of units sampled) that will cost the least amount of resources while still gaining accurate data for estimating population sizes. This point happens when there is little NEW information gained by additional sampling. **Indicate where this occurs on your graph by adding a STAR at this point.**

According to the graph you made, what is the ideal number of samples that should be taken to both minimize sampling effort while gaining the most information to accurately estimate populations?

Application.

In production systems, we don't have the actual pest population sizes to compare with our samples, thus ensuring accuracy. Instead, we rely on repeated sampling efforts and a variety of sampling techniques to get information about the pest populations present.

Next, you will use a hypothetical sampling plot where you will conduct THREE different types of samples. Each sampling method is commonly used, but each gives very different types of information. For each sampling method, assume you know nothing about the data found by the two other techniques: complete each technique one at a time, ignoring previous sampling results. Using the Practice Plot PDF (separate file), fill in the sampling card for each technique.

I. Presence/Absence Sample Card

Sample every plant in the row to fill out the table below. Only mark if the pest is present by placing an "X" in the column if the species appears.

PLANT No.	Species: (describe)	Species: (describe)	Species: (describe)	Species: (describe)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				

With P/A sampling, the intent is to get an idea of the pests present in the system by searching every without making hourly cost of scouts increase by requiring a count of each population. When do you think this kind of sampling is the most useful and economical for growers?

II. Fixed Random Sample Card

Look at your plot and mentally overlay a 3×3 grid that covers the entire plot of available plants (see diagram on the right). Determine which end of the practice plot contains units 1-3 and which has 7-9. Determine which plant is the closest to the center of each sample unit in your plot. Examine these nine plants closely and fill out the sample card below, adding a new row in each plot when there are more than one "species" of pest found.

Grid Unit No.	Pest(s)	Description	Number	Total Cumulative
Example	*Light Green*	*Light green +*	9	9
	Dark green	*Large, round circle*	1	10
1				
2				
3				
4				
5				
6				
7				
8				
9				

As you experienced, this type of sampling takes more time per plant, hence the need to reduce the number of plants sampled. Think about the first part of this activity, accuracy and precision and give one benefit and one drawback of using this type of sampling compared to the simpler Presence/Absence sampling event used for the previous sample card.

III. Sequential Sampling Card

Use the same nine plants identified in Sample Type II above. Check each plant for the light green "+"; if present, that plant is added to the tally as "1". Each positive result **adds to the running tally** in the vertical column titled "your tally". This column is **additive**– if the first three plants are all positive for the pest, then by the 3rdplant, there should be a "3" in the tally column. If plants 1 and 2 are positive, but 3 is negative, then there will still be a "2" in the tally column at the third plant.

Example:

Plant No.	Pest Present?	Don't Treat	**YOUR TALLY**	Treat
1	*Yes*	—	*1*	—
2	*Yes*	—	*2*	—
3	*No*	2	*2*	3
4	*Yes*	2	*3*	3
5	*No*	2	*3*	4

Compare your count to the "Treat" and "Don't Treat" recommendation columns to determine if pesticide management is necessary.

Plant No.	Pest Present?	Don't Treat	**YOUR TALLY**	Treat
1		—		—
2		—		—
3		2		3
4		2		3
5		2		4
6		3		4
7		3		5
8		3		6
9		4		6
10		4		7

For your nine plants, what is the recommendation for pest management?

Perform the sequential sampling a few times using different sampling patterns – one whole row, every other plant, ALL plants, etc. Did you consistently get the same pest management recommendation? Why/Why not?

What are the benefits and drawbacks of sequential sampling? When (in a production year/cycle) would this be the most useful means of sampling pests?

Wrap-Up Analysis

Insect identification is an important part of scouting for pests, especially when it comes to determining the difference between pests and similar-looking beneficial insects. However, training in identification for scouting jobs varies widely, which means there may not always be consistency in pest recognition and identification.

How do inconsistencies in identification change the precision and accuracy of each sampling type and analysis we've considered in this exercise?

WEEK 5: HEMIPTERA

Week 5 Materials

Reading

Week 5: Reading ….. [WEB]

Pre-lab 5 Download

Pre-lab 5 ……………. [WEB][PDF][WORD]

Lab 5 Download

Lab 5 Assignment … [WEB][PDF][WORD]

Week 5: Reading

Hemiptera

The True Bugs

Figure 5-1: *white flies are an example of this, family Aleyrodidae. Image source: https://www.flickr.com/photos/goshzilla/2502314165*

There are around 55,000 known species in Hemiptera (a super-Order containing the Homoptera and the Heteroptera). For the most part, the members of these groups are Paurometabolous but there are a few species in the Homoptera that have a pupae-like final juvenile stage (white flies are an example of this, family Aleyrodidae, figure 5-1) that is somewhat transitional in the evolution of the holometabola. Hemiptera may or may not have wings as adults, and some (like the aphids, family Aphididae) can have adults in the same species both with (alate) and without wings (apterous; figure 5-2). Other species always have wings as adults, like the Lygus bug (figure 5-3) in the Miridae family, and some species never have wings, like the Human parasite *Cimex lectularius*, the bed bug (figure 5-4).

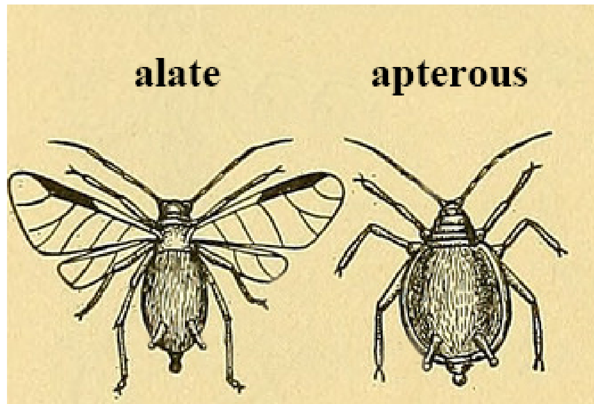


Figure 5-2: Apterous. *Image source: https://www.flickr.com/photos/internetarchivebookimages/20341240506/*

Figure 5-3: *Lygus bug (family Miridae). Image source: https://commons.wikimedia.org/w/index.php?title=File:Common_meadow_bug_-_Lygus_pratensis_(21273857975).jpg&oldid=270426472*

Figure 5-4: *bed bug (Cimex lectularius). Image source: http://pngimg.com/download/51953*

Hemiptera occupy a wide range of ecological niches and have very different life history strategies within the group, but a few characteristics make them easily distinguishable from the other orders. The Hemiptera are most frequently confused with the Coleoptera, which have hardened forewings and chewing mouthparts. Though it may be difficult to see the difference in wing types, mouthparts types for Hemiptera are always piercing/sucking, evident by the long beak visible either in profile or the underside of the insect. The hardened forewings in the Coleoptera, the *elytra*, are completely hardened, which is not the case in any of the Hemiptera. The wings of the Homoptera order are soft and malleable when present, and held tent-like above the body at rest; the wings of the Heteroptera are *half*-elytra. For the latter group, only the proximal part of the wing is thickened (though not hardened as in Coleoptera, but more like the tegmina of grasshopper forewings). The distal end of each wing is membranous, though it may still have a dark color. When at rest, the wings fold over each other on the dorsum of the insect and the two sections overlapping often create an easily identified "X" pattern. The elytra of Coleoptera always meet along the medial line without overlapping.

Most of the Hemiptera are terrestrial and plant feeders, using their beak/stylet to feed on plant fluids the way mosquitoes feed on animal blood. There are some that can even transmit plant diseases as they move from plant to plant to feed (example: Tomato Leaf Curl Virus). Many of these plant feeding Hemiptera are therefore serious economical pests. There are a few members of the Hemiptera, primarily in the Heteroptera, that are economically important beneficial insects, acting as natural enemies of many other insects and arthropods, including other Hemiptera. A few examples of these are Assasin bugs (family Reduviidae, figure 5-5), and minute pirate bugs (family Anthocoridae, figure 5-6), and even one predaceous species of Stink Bug, family Pentatomidae (figure 5-7).

Figure 5-5: *Assasin bugs (family Reduviidae). Image source: https://www.flickr.com/photos/diazseptsix/14871160622*

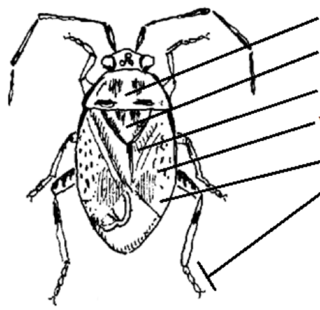
Figure 5-6: *minute pirate bugs (family Anthocoridae). Image source: https://en.wikipedia.org/wiki/File:Orius_insidiosus_from_USDA_2_(cropped).jpg*

Figure 5-7: *Stink Bug (family Pentatomidae). Image source: https://commons.wikimedia.org/w/index.php?title=File:Pentatomidae_-_Halyomorpha_halys-001.JPG&oldid=323146426*

Pre-Lab 5: Pests, Predators and Parasitoids, Part I

Name: ______________________________________

Part I. Hemiptera Bauplan



Part II. Hemiptera Ecology

1. The Brown Marmorated Stink Bug has received a great deal of attention as a recent invasive species across the US. OSU has done a great deal of work evaluating Natural Enemies of BMSB, but UC Nursery and Floriculture has great basic information on this invader. Read the information and answer the following:
    1. What is the scientific name of this invader? ____
    2. BMSB is very close in appearance to our native Rough Stink Bug. Give two reliable characteristics for telling these two insects apart on sight.
    3. From where did this insect originate? ____
    4. Why has the BMSB been so successful invading new habitat in the US?
    5. What natural enemies can control BMSB populations in its native region?
    6. What natural enemies exist in Oregon that can aid in population management for BMSB? Where have they been found?
2. This week's lab reading mentions Assassin bugs in the family Reduviidae as predators, but there are members of this family that are also pests to humans living in South America all the way north to the southern US states (CDC Weblink). What Reduviid is a pest to humans (common name is fine), and how?

3. Aphids are probably the most widespread and common pest in nearly every crop. List SIX natural enemies in the Western US that have been commercialized for aphid control (UC IPM PestNotes, Natural Enemies BioControl

(inactive link as of 05/24/2021), Evergreen Growers Supply).

1. ____________________________________ 4. ____________________________________

2. ____________________________________ 5. ____________________________________

3. ____________________________________ 6. ____________________________________

Lab 5 Assignment: Pests, Predators and Parasitoids, Part I

Name: ______________________________________

Part I. Pests, Predators and Parasitoids

Review the information provided for two natural enemies: 1. *Chrysoperla* Lacewing larvae (predator); and 2. *Aphidius* wasps (parasitoids).

1. In your examination of the information, which do you think is the most effective at controlling cabbage aphid populations in an enclosed (greenhouse) setting? Why?
    1. Which do you think is the most effective in an outdoor system? Why?

2. Give examples of two conditions that may disrupt the efficacy of these predators (be specific – which predator and why?

Experiment: We are going to test the application rates for **ONE** of these natural enemies. We will need a **positive** and a **negative** control group. A positive control gets the result we want; conversely, we should not get the response you want in the negative control group. Without worrying about replication in this lab, we are going to create small studies that can be addressed with the pest/predator/parasitoid model available in lab with only one variable. Examples:

1. Satiation rates (how many will they eat/time)
2. Survival rates for aphids/natural enemies/time
3. Comparative efficacy (set up for ONE predator)
4. Efficacy with varied pest density (choose only one biocontrol agent)
5. Cannibalism rates (lacewings only)

1. **Formulate your study question:**
2. **Predict the outcome:**
3. **Describe your method:**

3. Identify the:

Positive Control Group: ____

Negative Control Group: ____

Test Group(s): ____

____

____

Create a DATA COLLECTION SHEET that could be used to manage the data that will answer the study question on this sheet.

Natural Enemy: ____

Part II. Pests – Identification

Obtain a “known” specimen from the class collection. Remember where you selected your specimen (the family) so that you can return it to the correct box.

1. Use your key to identify the specimen to the correct Family (which is known since the specimens are labeled). As you move through the key, record each line (e.g. 1a) you selected, and draw each characteristic described as seen on the specimen.

2. Do the same with a Hemipteran specimen that you have collected or one from those provided (“unknown”). When you finish your ID, check with the instructor to make sure you are correct, and obtain a signature: ____________

Review: Curation

The correct pin placement for all insects pictured is to the right of the midline. Additionally, insects glued onto “points” are also glued only on the right side. Why is this? What is the purpose?

Demonstrate proper pinning technique for two specimens, one pinned and one on a point. Have each checked by the lab instructor, who will initial the space below when each is completed correctly.

Pinned Specimen: ___________________________

Pointed Specimen: __________________________

A moth in the family Noctuidae was caught by your instructor this morning on the lawn outside of Cordley Hall. Given this information, demonstrate the information presented on the labels for this insect:

Upper Label:

Order
Family
Identified by:

Lower Label:

Location Collected (County/Habitat)
Date Collected
Collected by:

How are spiders and other non-insect arthropods preserved?

WEEK 6: PESTS, PREDATORS, AND PARASITOIDS, PT. II

Week 6 Materials

Reading

Week 6: Reading ….. [WEB]

Pre-lab 6 Download

Pre-lab 6 ……………. [WEB][PDF][WORD]

Lab 6 Download

Lab 6 Assignment … [WEB][PDF][WORD]

Week 6: Reading

Pests, Predators, & Parasitoids: Part II

The Order **Hymenoptera** (meaning "Membranous Wing") includes the ants, bees, wasps, and sawflies. More than 120,000 species have been identified, including most recently a discovery of 70 species of microwasps in Thailand. Though this group is known for charismatic macro species, these tiny wasps make up the majority of the diversity in this order.

The name Hymenoptera refers to the 2 pairs of wings that are usually clear (though they may be dark), with the forewings larger than the hindwings. Additionally, the venation in the hind wing is greatly reduced, even in the macro species (the micro species have little venation at all in both wing pairs). The anterior margin of the hind wing will also often be equipped with a row of hooks that allow the hind wing to attach to the forewing; these hooks are called "hamuli".

Hymenoptera are holometabolous, with a maggot-like immature stage preceding the pupal stage. Both the larvae and the adults are equipped with chewing mouthparts, though there are some adaptations for lapping using a tongue-like **glossae** in the nectar-feeding species. The females in Hymenoptera typically have well-developed ovipositors with many species modified for stinging/venom delivery, i.e. the stingers of bees and wasps (figure 6-1).

There are two sub-orders of Hymenoptera, the Apocrita and the Symphyto. The Apocrita are identified by the separation of the basal segment of the abdomen and the thorax by a constriction, appearing as a "narrow waist" that is the petiole. Most larval Apocrita feed on other arthropods although phytophagy has reevolved several times. The abdomen of the Symphyta is joined broadly to the thorax, and nearly all are phytophagous (plant feeders).

One of the most interesting aspects of Hymeoptera biology is the evolution of a gradient of social complexities, from highly complex hives of honeybees to the solitary individuals in contact with members of their own species only for mating purposes, with many parasocial species in between these two extremes.

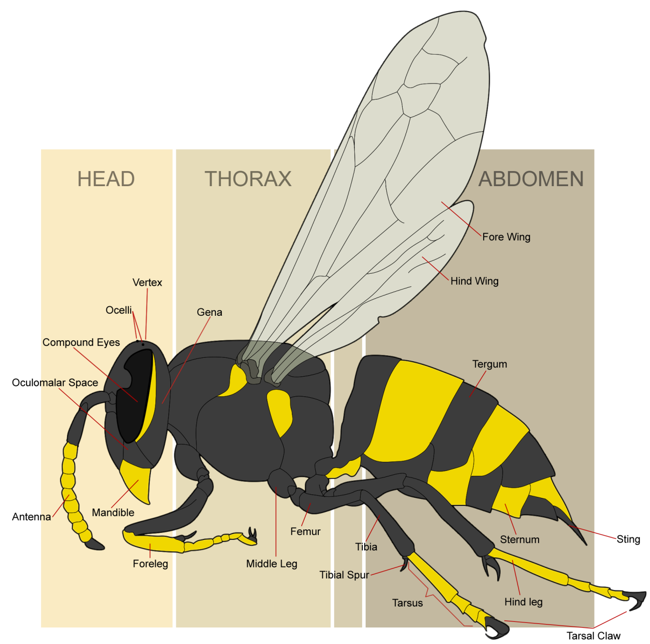


Figure 6-1: *Order Hymenoptera which includes ants, bees, wasps and sawflies. Image source: https://en.wikipedia.org/wiki/Vespula#/media/File:Wasp_morphology.png*

Many important pollinators in natural and managed landscapes belong to the Hymenoptera, and though they are not thought to be the first insects that pollinated plants (that honor goes to the Coleoptera), they are the group that celebrates the most physiological adaptation specific to providing this ecosystem service. The presence of the elongate glossae in the honeybees and bumble bees as a nectar-lapping structure is an example of this evolution, as are the structures on the legs and abdomen used for carrying either dry pollen or pollen balls mixed with nectar and saliva more easily. Behaviors utilized by colonies to communicate the location of rich food resources and physiology enhancing sensory detection of floral resources adds the the efficacy and success of the mutualism between pollinators and plants.

However, where there is fair trade, there will also always evolve means of cheating the system, and this has come about as well, on both sides of the symbiosis. Some bee species have bypassed the responsibility of pollination services by cutting into the carpel of the flower to extract the nectar. This is known as "nectar robbing", cheating the flower of its potential to outcross and robbing the sugar-rich stores that would have fueled a true pollinator. Some plants have also found ways to take advantage of pollinator services without rewarding the assistance as well, but enticing the insects to the plant but providing no food resource in exchange.

The order **Neuroptera** is a diverse group of predatory insects with equipped with dense venation in the wings, seen as a network. It is this characteristic for which they are named. This group includes the lacewings, owlflies, and antlions, and used to include the Snakeflies (now order **Rhaphidioptera**). There are more than 5000 known species.

Members of the Neuroptera and Raphidioptera are holometabolous. They can be identified roughly by visual characteristics of the wings: the forewings are larger than the hindwings and have many veins and cross veins, appearing as a nerve network. In particular, numerous parallel humeral cross veins between the costal vein and the sub-costa should be visible. When at rest, the wings are held tent-like over the abdomen, and no terminal cerci will be present (although many females of different species have obvious ovipositors that may appear similar to cerci). All members of these orders have chewing mouthparts and are voracious predators, and many are considered beneficial in cropping systems.

Most members of these Orders are weak fliers, and are active mostly at night. Some will be attracted to lights and will gather in search of prey. Females will lay eggs in locations with available prey, many of the eggs unique. For example, the eggs of green lacewings are laid individually, each at the end of a long stalk. The larvae are predaceous at hatch, and this method prevents cannibalism (figure 6-2).

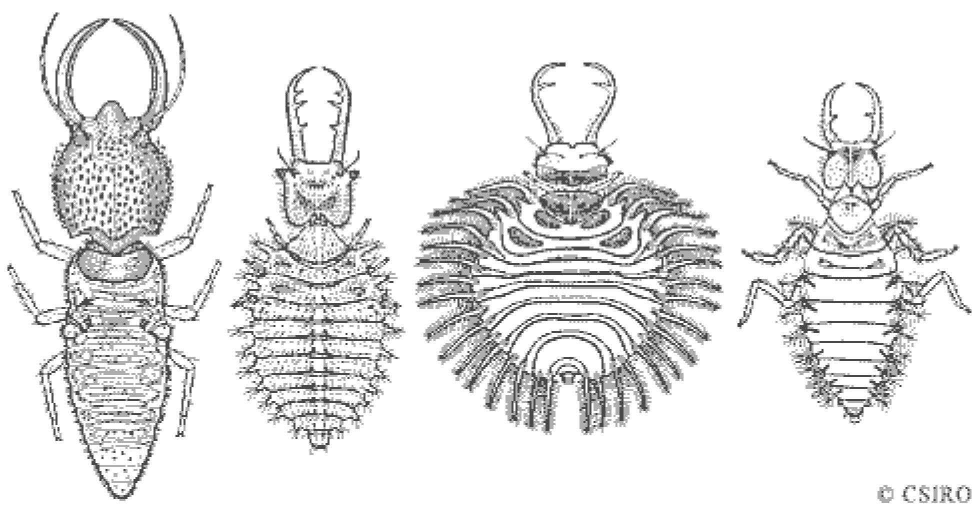


Figure 6-2: *Examples of Neuroptera Larvae. Image source: http://www.ento.csiro.au/education/insects/neuroptera.html*

Pre-Lab 6: Pests, Predators and Parasitoids, Part II

Name: ___________________________________

Part I. Natural Enemies

When damaging species appear in agro-ecosystems, pesticides and other control means are usually readily available for control. However, identify and harnessing natural enemies of the pest already present can save time, money and crop value. There are several "types" of natural enemies that can be used for biocontrol: Predators, Parasites and Parasitoids.

1. Define and give one insect example of each, naming the ORDER of your example insect:
    1. Pest:
    2. Predator:
    3. Parasite:
    4. Parasitoid:
2. For the pest/parasitoid complex named below, describe the MONITORING techniques you would use to identify any natural enemies (inactive link as of 5/24/2021) (hint: think about where the pests live, HOW the parasitoid finds prey, and the pest stage parasitized)
    1. Aphid/Trichogrammatid Wasp
    2. Apple Codling Moth/Tachinid Fly
    3. Cutworm/Ichneumonid Wasp

Identification: Using the key provided to you, identify one of this week's new specimens to family, correctly curate and label the specimen (both labels). Present this specimen to the instructor with this week's specimens.

Lab 6 Assignment: Collection/Field Sampling

Name: ____________________________________

Part I. Soil/Leaf Litter Samples

We are going to make use of the bank of Berlese funnels in the back of the classroom (finally!). As a class, we're going to examine the soil arthropod communities in response to two dimensions: linear distance from edge habitat and soil depth.

1. Linear Distance Samples

At our study site, we'll begin at the immediate edge of a chosen habitat or disturbance and take our first edge-habitat sample. We will remove the upper 10 x 10 x 10 cm of soil/leaf litter. The second sample will be taken 10 meters from the selected start-point and the third will be 20 meters from the start-point. The samples will be of equal size. Each will be clearly labeled and brought back to the classroom.

2. Soil Depth

At the FIRST linear distance sample location (0m), two additional samples will be taken of the next successive 10cm of soil each (depth = 20 cm, depth = 30cm). These will also be clearly labeled and returned to the classroom.

The class will be broken into groups responsible for each soil sample. Once you have collected and clearly labeled your soil sample, we will have time to collect for approximately 30 minutes before returning to the classroom to complete lab.

1. What was your specific role in collecting soil samples for lab?

2. What differences in arthropod communities would you expect to see along the linear transect?

3. What differences would you expect to see in arthropod morphology with increasing soil depth?

Part II. Collection Review

Today, we're using the Berlese funnels to survey for soil arthropods. Is this an active or passive collection technique?

Which collection method is the best for capturing insects with piercing/sucking mouthparts on ornamental trees and shrubs?

Which collection method is the best for nocturnal, ground-dwelling insect? Is this active or passive collection?

Using the Pocket Guide provided, give three ways to monitor a production system for the presence of natural enemies:

1. ____

2. ____

3. ____

WEEK 7: SOIL INSECTS

Week 7 Materials

Reading

Week 7: Reading ..... [WEB]

Pre-lab 7 Download

Pre-lab 7 .... [WEB][PDF][WORD]

Lab 7 Download

Lab 7 Assignment ... [WEB][PDF][WORD]

Week 7: Reading

Soil Arthropods

By Andrew R. Moldenke, Oregon State University

THE LIVING SOIL: ARTHROPODS

Many bugs, known as arthropods, make their home in the soil. They get their name from their jointed (arthros) legs (podos). Arthropods are invertebrates, that is, they have no backbone, and rely instead on an external covering called an exoskeleton (figure 7-1).

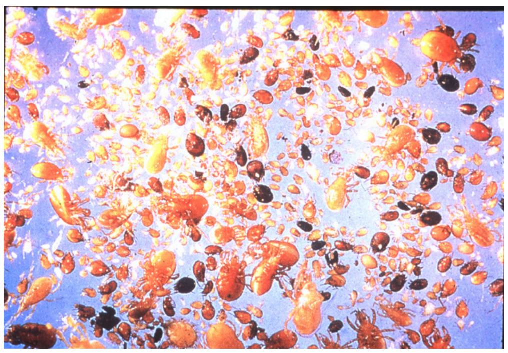


Figure 7-1: *The 200 species of mites in this microscope view were extracted from one square foot of the top two inches of forest litter and soil. Mites are poorly studied, but enormously significant for nutrient release in the soil.* ***Credit:*** *Val Behan-Pelletier, Agriculture and Agri-Food Canada. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Arthropods range in size from microscopic to several inches in length. They include insects, such as springtails, beetles, and ants; crustaceans such as sowbugs; arachnids such as spiders and mites; myriapods, such as centipedes and millipedes; and scorpions.

Nearly every soil is home to many different arthropod species. Certain row-crop soils contain several dozen species of arthropods in a square mile. Several thousand different species may live in a square mile of forest soil.

Arthropods can be grouped as shredders, predators, herbivores, and fungal-feeders, based on their functions in soil. Most soil-dwelling arthropods eat fungi, worms, or other arthropods. Root-feeders and dead-plant shredders are less abundant. As they feed, arthropods aerate and mix the soil, regulate the population size of other soil organisms, and shred organic material.

Shredders

Many large arthropods frequently seen on the soil surface are shredders. Shredders chew up dead plant matter as they eat bacteria and fungi on the surface of the plant matter. The most abundant shredders are millipedes and sowbugs, as well as termites, certain mites, and roaches. In agricultural soils, shredders can become pests by feeding on live roots if sufficient dead plant material is not present (figure 7-2 & figure 7-3).

Figure 7-2: *Millipedes are generally harmless to people, but most millipedes protect themselves from predators by spraying an offensive odor from their skunk glands. This desert-dwelling giant millipede is about 8 inches long. Orthoporus ornatus. (photo cr. David B. Richman)*

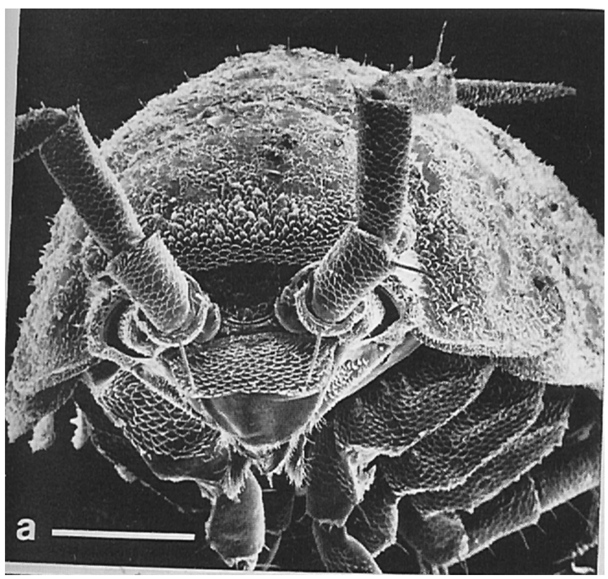


Figure 7-3: *Sowbugs are relatives of crabs and lobsters. Their powerful mouth-parts are used to fragment plant residue and leaf litter.* **Credit:** *Gerhard Eisenbeis and Wilfried Wichard. 1987. Atlas on the Biology of Soil Arthropods. Springer-Verlag, New York. P. 111. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Predators

Predators and micropredators can be either generalists, feeding on many different prey types, or specialists, hunting only a single prey type. Predators include centipedes, spiders, ground-beetles, scorpions, skunk-spiders, pseudoscorpions, ants, and some mites. Many predators eat crop pests, and some, such as beetles and parasitic wasps, have been developed for use as commercial biocontrols (figure 7-4, figure 7-5, figure 7-6, figure 7-7, figure 7-8, figure 7-9, & figure 7-10).

Figure 7-4: *This 1/8 of an inch long spider lives near the soil surface where it attacks other soil arthropods. The spider's eyes are on the tip of the projection above its head. Walckenaera acuminata.* ***Credit:*** *Gerhard Eisenbeis and Wilfried Wichard. 1987. Atlas on the Biology of Soil Arthropods. Springer-Verlag, New York. P. 23. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Figure 7-5: *The wolf-spider wanders around as a solitary hunter. The mother wolf-spider carries her young to water and feeds them by regurgitation until they are ready to hunt on their own.* ***Credit:*** *Trygve Steen, Portland State University, Portland, Oregon. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

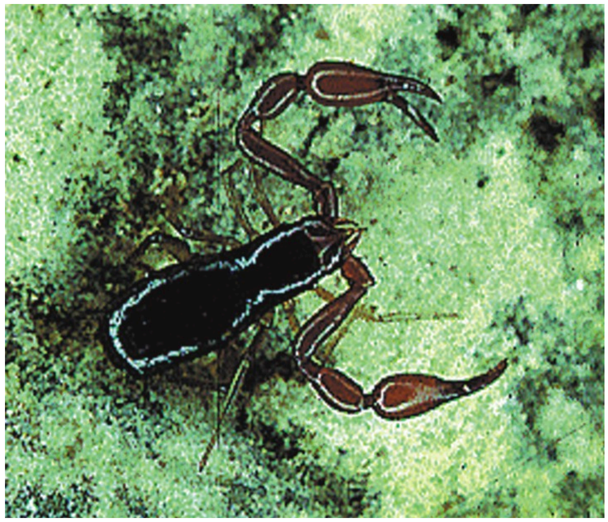


Figure 7-6: *The pseudoscorpion looks like a baby scorpion, except it has no tail. It produces venom from glandsin its claws and silk from its mouth parts. It lives in the soil and leaf litter of grasslands, forests, deserts and croplands. Some hitchhike under the wings of beetles.* **Credit:** *David B. Richman, New Mexico State University, Las Cruces. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Figure 7-7: *Long, slim centipedes crawl through spaces in the soil preying on earthworms and other soft-skinned animals. Centipede species with longer legs are familiar around homes and in leaf litter.* **Credit:** *No. 40 from Soil Microbiology and Biochemistry Slide Set. 1976. J.P. Martin, et al., eds. SSSA, Madison, WI.*

***Figure 7-8:** Predatory mites prey on nematodes, springtails, other mites, and the larvae of insects. This mite is 1/25 of an inch (1mm) long. Pergamasus sp. **Credit:** Gerhard Eisenbeis and Wilfried Wichard. 1987. Atlas on the Biology of Soil Arthropods. Springer-Verlag, New York. P. 83. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Figure 7-9: *The powerful mouthparts on the tiger beetle (a cicindellid beetle) make it a swift and deadly ground-surface predator. Many species of carabid beetles are common in cropland.* **Credit:** *Cicindela campestris. D.I. McEwan/Aguila Wildlife Images. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Figure 7-10: *Rugose harvester ants are scavengers rather than predators. They eat dead insects and gather seeds in grasslands and deserts where they burrow 10 feet into the ground. Their sting is 100 times more powerful than a fire ant sting. Pogonomyrmex rugosus.* ***Credit:*** *David B. Richman, New Mexico State University, Las Cruces. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Herbivores

Numerous root-feeding insects, such as cicadas, mole-crickets, and anthomyiid flies (root-maggots), live part of all of their life in the soil. Some herbivores, including rootworms and symphylans, can be crop pests where they occur in large numbers, feeding on roots or other plant parts (figure 7-11).

***Figure 7-11:** The symphylan, a relative of the centipede, feeds on plant roots and can become a major crop pest if its population is not controlled by other organisms.**Credit:** Ken Gray Collection, Department of Entomology, Oregon State University, Corvallis. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

Fungal Feeders

Arthropods that graze on fungi (and to some extent bacteria) include most springtails, some mites, and silverfish. They scrape and consume bacteria and fungi off root surfaces. A large fraction of the nutrients available to plants is a result of microbial-grazing and nutrient release by fauna (figure 7-12 & figure 7-13).

Figure 7-12: *This pale-colored and blind springtail is typical of fungal-feeding springtails that live deep in the surface layer of natural and agricultural soils throughout the world.* ***Credit:*** *Andrew R. Moldenke, Oregon State University, Corvallis. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images.*

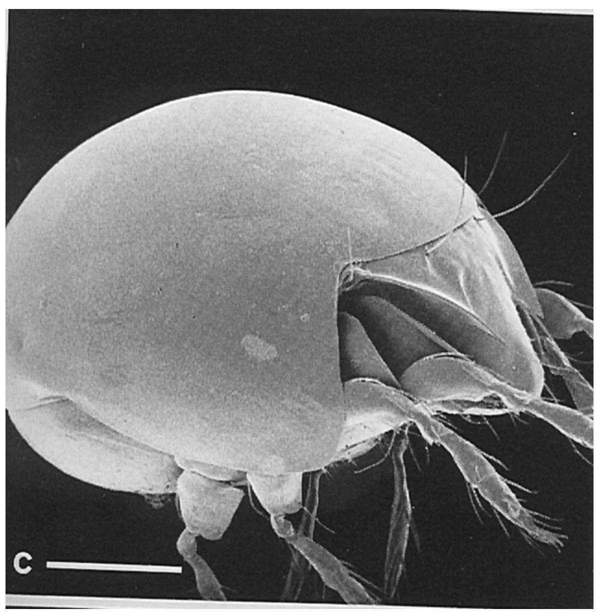


Figure 7-13: *Oribatid turtle-mites are among the most numerous of the micro-arthropods. This millimeter-long species feeds on fungi. Euzetes globulus.* ***Credit:*** *Gerhard Eisenbeis and Wilfried Wichard. 1987. Atlas on the Biology of Soil Arthropods. Springer-Verlag, New York. P. 103. Please contact the Soil and Water Conservation Society at pubs@swcs.org for assistance with copyrighted (credited) images*

What Do Arthropods Do?

Although the plant feeders can become pests, most arthropods perform beneficial functions in the soil-plant system.

Shred organic material.

Arthropods increase the surface area accessible to microbial attack by shredding dead plant residue and burrowing into coarse woody debris. Without shredders, a bacterium in leaf litter would be like a person in a pantry without a can-opener – eating would be a very slow process. The shredders act like can-openers and greatly increase the rate of decomposition. Arthropods ingest decaying plant material to eat the bacteria and fungi on the surface of the organic material.

Stimulate microbial activity.

As arthropods graze on bacteria and fungi, they stimulate the growth of mycorrhizae and other fungi, and the decomposition of organic matter. If grazer populations get too dense the opposite effect can occur – populations of bacteria and fungi will decline. Predatory arthropods are important to keep grazer populations under control and to prevent them from over-grazing microbes.

Mix microbes with their food.

From a bacterium's point-of-view, just a fraction of a millimeter is infinitely far away. Bacteria have limited mobility in soil and a competitor is likely to be closer to a nutrient treasure. Arthropods help out by distributing nutrients through the soil, and by carrying bacteria on their exoskeleton and through their digestive system. By more thoroughly mixing microbes with their food, arthropods enhance organic matter decomposition.

Mineralize plant nutrients.

As they graze, arthropods mineralize some of the nutrients in bacteria and fungi, and excrete nutrients in plant-available forms.

Enhance soil aggregation.

In most forested and grassland soils, every particle in the upper several inches of soil has been through the gut of numerous soil fauna. Each time soil passes through another arthropod or earthworm, it is thoroughly mixed with organic matter and mucus and deposited as fecal pellets. Fecal pellets are a highly concentrated nutrient resource, and are a mixture of the organic and inorganic substances required for growth of bacteria and fungi. In many soils, aggregates between 1/10,000 and 1/10 of an inch (0.0025mm and 2.5mm) are actually fecal pellets.

Burrow.

Relatively few arthropod species burrow through the soil. Yet, within any soil community, burrowing arthropods and earthworms exert an enormous influence on the composition of the total fauna by shaping habitat. Burrowing changes the physical properties of soil, including porosity, water-infiltration rate, and bulk density.

Stimulate the succession of species.

A dizzying array of natural bio-organic chemicals permeates the soil. Complete digestion of these chemicals requires a series of many types of bacteria, fungi, and other organisms with different enzymes. At any time, only a small subset of species is metabolically active – only those capable of using the resources currently available. Soil arthropods consume the dominant organisms and permit other species to move in and take their place, thus facilitating the progressive breakdown of soil organic matter.

Control pests.

Some arthropods can be damaging to crop yields, but many others that are present in all soils eat or compete with various root- and foliage-feeders. Some (the specialists) feed on only a single type of prey species. Other arthropods (the generalists), such as many species of centipedes, spiders, ground-beetles, rove-beetles, and gamasid mites, feed on a broad range of prey. Where a healthy population of generalist predators is present, they will be available to deal with a variety of pest outbreaks. A population of predators can only be maintained between pest outbreaks if there is a constant source of non-pest prey to eat. That is, there must be a healthy and diverse food web.

A fundamental dilemma in pest control is that tillage and insecticide application have enormous effects on non- target species in the food web. Intense land use (especially monoculture, tillage, and pesticides) depletes soil diversity. As total soil diversity declines, predator populations drop sharply and the possibility for subsequent pest outbreaks increases.

Where Do Arthropods Live?

The abundance and diversity of soil fauna diminishes significantly with soil depth. The great majority of all soil species are confined to the top three inches. Most of these creatures have limited mobility, and are probably capable of "cryptobiosis," a state of "suspended animation" that helps them survive extremes of temperature, wetness, or dryness that would otherwise be lethal.

As a general rule, larger species are active on the soil surface, seeking temporary refuge under vegetation, plant residue, wood, or rocks. Many of these arthropods commute daily to forage within herbaceous vegetation above, or even high in the canopy of trees. (For instance, one of these tree-climbers is the caterpillar-searcher used by foresters to control gypsy moth). Some large species capable of true burrowing live within the deeper layers of the soil.

Below about two inches in the soil, fauna are generally small – 1/250 to 1/10 of an inch. (Twenty-five of the smallest of these would fit in a period on this page.) These species are usually blind and lack prominent coloration. They are capable of squeezing through minute pore spaces and along root channels. Sub-surface soil dwellers are associated primarily with the rhizosphere (the soil volume immediately adjacent to roots).

Abundance of Arthropods

A single square yard of soil will contain 500 to 200,000 individual arthropods, depending upon the soil type, plant community, and management system. Despite these large numbers, the biomass of arthropods in soil is far less than that of protozoa and nematodes.

In most environments, the most abundant soil dwellers are springtails and mites, though ants and termites predominate in certain situations, especially in desert and tropical soils. The largest number of arthropods are in natural plant communities with few earthworms (such as conifer forests). Natural communities with numerous earthworms (such as grassland soils) have the fewest arthropods. Earthworms out-compete arthropods, perhaps by excessively reworking their habitat or eating them incidentally. However, within pastures and farm lands arthropod numbers and diversity are generally thought to increase as earthworm populations rise. Burrowing earthworms probably create habitat space for arthropods in agricultural soils.

Bug Biography: Springtails

Figure 7-14: *Springtails are the most abundant arthropod.*

Springtails are the most abundant arthropods in many agricultural and rangeland soils (figure 7-14). Populations of tens of thousands per square yard are frequent. When foraging, springtails walk with 3 pairs of legs like most insects, and hold their tail tightly tucked under the belly. If attacked by a predator, body fluid rushes into the tail base, forcing the tail to slam down and catapult the springtail as much as a yard away. Springtails have been shown to be beneficial to crop plants by releasing nutrients and by feeding upon diseases caused by fungi.

Collembola Families: Photo Guide (figure 7-15)

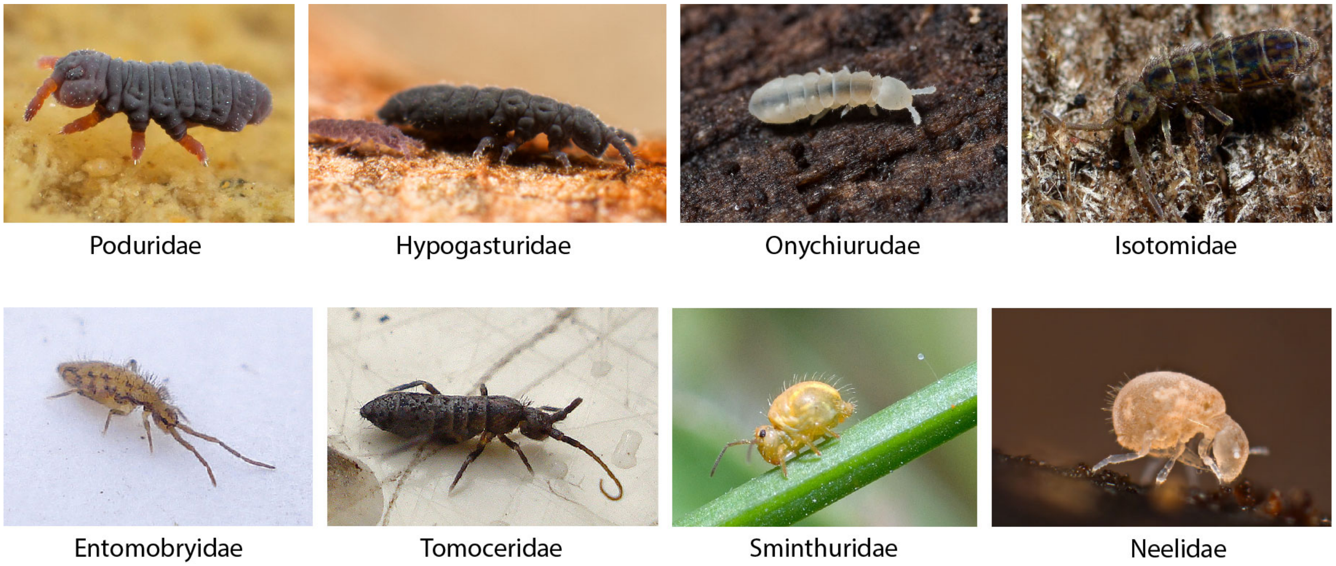


Figure 7-15: *Poduridae, Hypogasturidae, Onychiurudae, Isotomidae, Entomobrydae, Tomoceridae, Sminthuridae, & Neelidae. Image sources top row (from left to right): https://www.collembola.org/images/uk/michaelson/Podura-aquatica-20100709-Jonathan-Michaelson-UK-Berkshire-l.jpg, https://ru.wikipedia.org/wiki/Файл:Hypogastrura_viatica_(8281139214).jpg, https://www.flickr.com/photos/32977858@N02/36959419253, https://www.flickr.com/photos/34878947@N04/32971082545 Image sources bottom row (from left to right): https://www.flickr.com/photos/25258702@N04/3349661151/, https://www.flickr.com/photos/micks-wildlife-macros/3267532814/, https://en.wikipedia.org/wiki/Sminthurus_viridis, https://www.flickr.com/photos/andybadger/8434285511*

Pre-Lab 7

Name: ___________________________________

Supplementary: Soil Arthropods

1. Arthropods that spend the majority of their time/life cycle in the leaf litter are typically well adapted for their habitat. From the reading, give TWO specific examples of the way sensory structures and functions differ in soil/leaf-litter dwelling arthropods in comparison to typical terrestrial arthropods.

Management of Soil Pests

Many of the soil insects that behave as pests in production systems only do so when occurring in high numbers. Then, because of the protective nature of soil habitat, they are often frequently difficult to treat, especially which topical pesticides that require heavy contact with the organism.Review your tools of IPM (inactive link as of 05/24/2021) and provide a solution for each of the following scenarios:

1) A way to EXCLUDE soil pests in a plant nursery that does not include pesticides:

2) A way to manage soil pest populations below injury levels once they've invaded, that does not include pesticides:

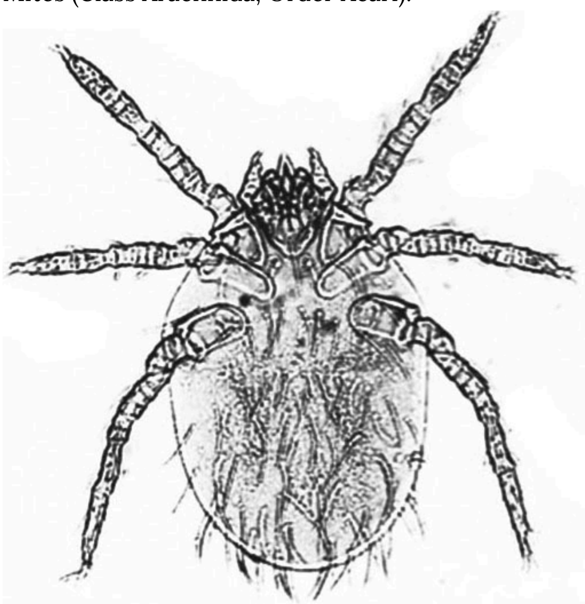
3) A way to decrease soil pest population with no risk of harming beneficial insects/arthropods that may be on foliage:

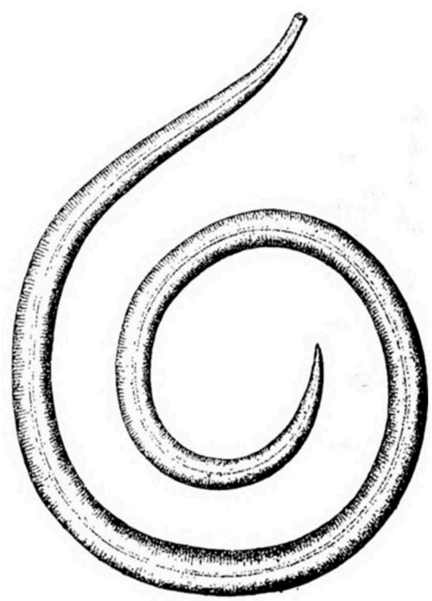
Lab 7 Assignment: Soil Arthropods

Guide to Common Soil Arthropods **Name: ____________________________**

PART I. Identification

Mites (Class Arachnida, Order Acari):

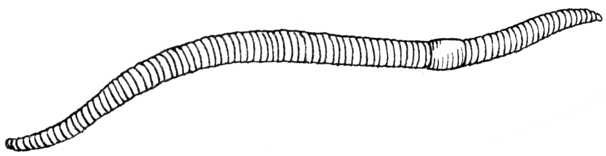




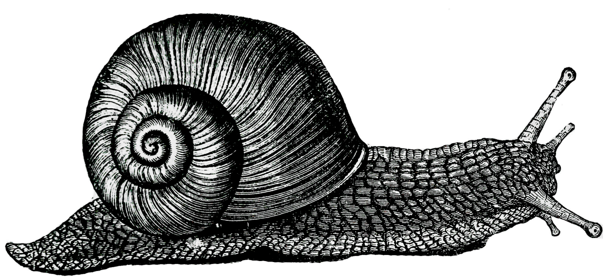
Round Worms (Phylum Nematoda):

Segmented Worms
(Phylum Annelida, Class Oligochaeta):

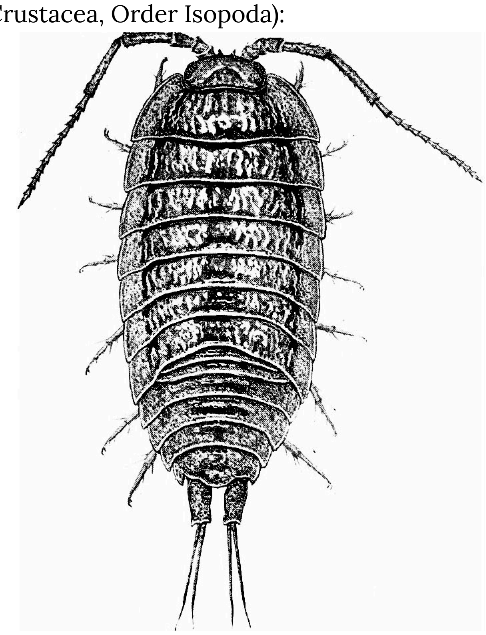
Leeches (Phylum Annelida, Class Hirundinea):



Snails, Slugs (Phylum Mollusca, Class Gastropoda):

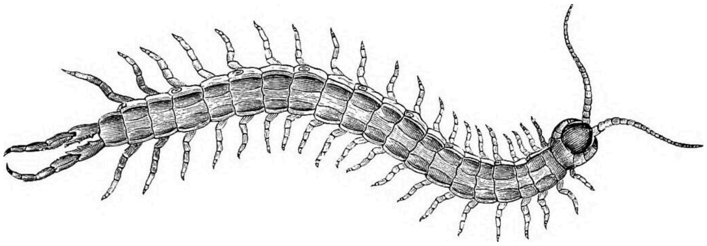


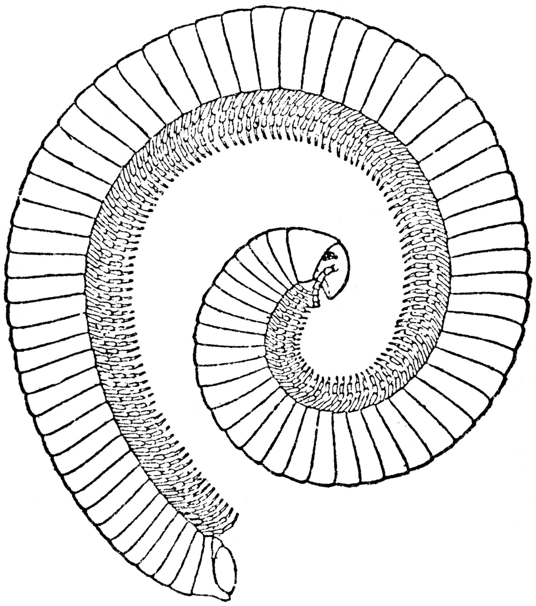
Isopod (Phylum Crustacea, Order Isopoda):



Centipedes (Phylum Uniramia, Class Chilopoda):

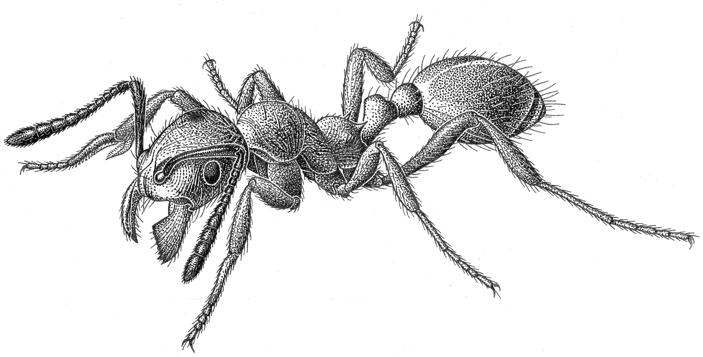
Millipedes (Phylum Uniramia, Class Diplopoda):



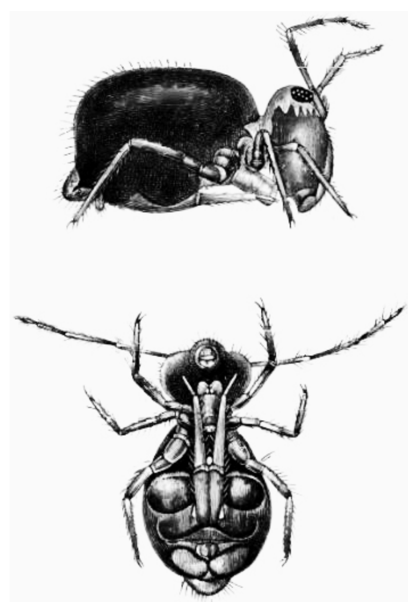


Insects (Phylum Arthropoda, Class Insecta)

Hymenoptera: Formicidae
Ants

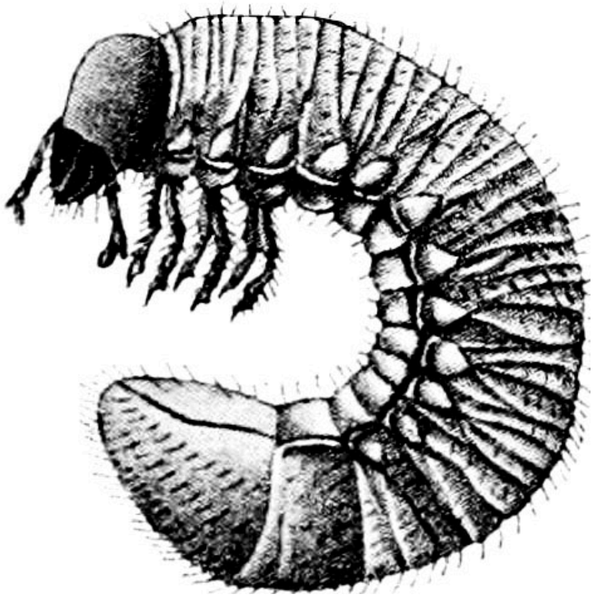


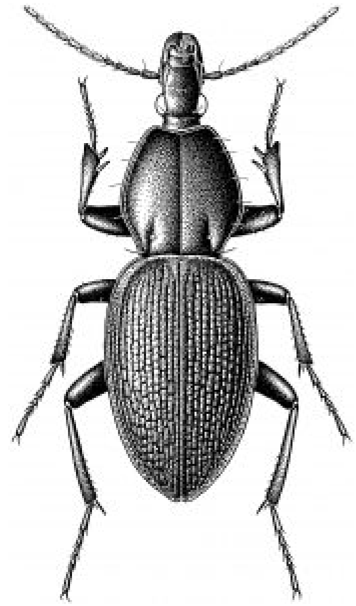
Collembola
Springtails



Coleoptera
Beetles (grubs)

Coleoptera
Beetles (adults)





Additional, Morpho-species (draw and describe each of the “artificial” designations used in your data reporting):

Data Collection

Collection Site Name	TAXA/Morpho-species	TALLY	TOTALS

Part II. Soil Arthropods Study

1. Report your results – major trends, morphological differences in guilds between samples, etc.

LINEAR TRANSECT:

DEPTH PROFILE:

2. Discuss your results – **why** did the arthropod assemblages vary as they did in your samples?

Part III. Identification

Create a Dichotomous Key for the organisms identified in your group samples: these are set up as couplets of two choices that are opposite. For example:

1A. Shape **does not have** discernible "sides" … …**CIRCLE**
1B. Shape **has** discernible sides … … 2

2A. Sides of shape are all of equal length… …3

2B. Sides of shape are not all of equal length… …**RECTANGLE**

3A. Shape has three sides … …**TRIANGLE**
3B. Shape has four sides … …**SQUARE**

Select SIX of the soil organisms you identified in this lab and create a dichotomous key that can be used to identify them.

Key approved by: ____

WEEK 8: POLLINATORS

Week 8 Materials

Reading

Week 8: Reading .... [WEB]

Supplemental Reading ... [PDF]

Pre-lab 8 Download

Pre-lab 8 .... [WEB][PDF][WORD]

Lab 8 Download

Lab 8 Assignment .... [WEB][PDF][WORD]

Week 8: Reading

GAIL LANGELLOTTO AND MELISSA SCHERR

Pollinators

***Figure 8-1:** A pollinator at work. Animals pollinate an estimated 80% of the world's flowering plants (Ollerton et al. 2011) and 75% of global crop species (Klein et al. 2007). Image source: https://pxhere.com/en/photo/476115*

Animals pollinate an estimated 80% of the world's flowering plants (Ollerton et al. 2011) and 75% of global crop species (Klein et al. 2007) (figure 8-1). Pollinators are critical to fruit production and seed set in many of Oregon's key crops, including tree fruits, berries, melons, and specialty seed crops (e.g. carrot seed). Not only do pollinators increase crop yield, but in many cases, they improve crop quality.

Pollinators visit flowers to collect nectar for flight fuel and pollen for brooding; nectar is a good source of carbohydrates, while pollen is a good source of protein. When a pollinator visits a flower in search of food, they often brush against plant reproduction structures. When they move between flowers (for dioecious or monoecious plants) or within a flower (for plants with perfect flowers), pollinators can transfer pollen from the anther to the stigma, thus facilitating fertilization.

Bees are arguably the most efficient and most effective of pollinators. Other types of insect pollinators include flies, ants, wasps, beetles, butterflies, and moths. Vertebrate pollinators include hummingbirds, bats, and even rodents. The first pollinators were thought to be beetles feeding on conifer sap that forms on cones, and the resultant pollination efficiency as the beetles moved between male and female cones drove the evolution of the Angiosperms and their flowers. The first angiosperms reliant on pollination by insects were typically open-faced flowers with shallow food resources or fleshy petals: there needed to be an accommodation for both the larger stance of the beetle and unadapted chewing mouthparts. Many of these beetles still feed on primitive angiosperms at least in part, like the predatory Checkered Flower beetle that feeds on Oxeye Daisy pollen in the spring months (figure 8-2).

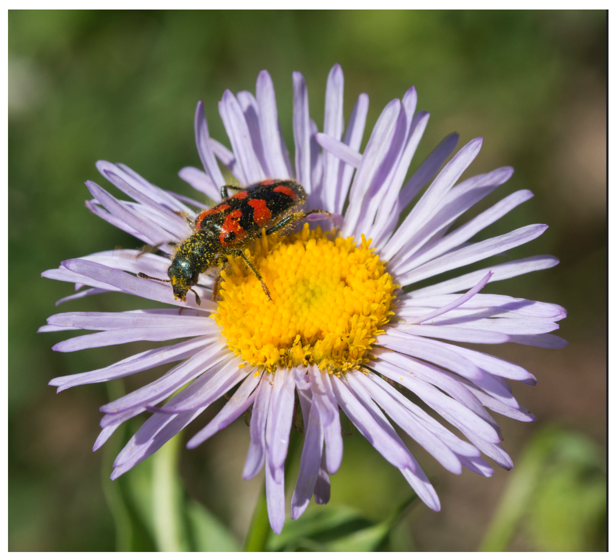


***Figure 8-2:** The Checkered Flower Beetle feeds on Oxeye Daisy pollen in the spring months. Image source: https://www.flickr.com/photos/39422575@N02/43562484571/in/photolist-29nt7Yc-298QFWi-DR4KGe-K2AEag-o5kg55-oqXzcM-xaiVv-9pmwXr-6zH6fP-6M3USZ-o9sSSd-27nLNkJ-FDKzKP-fC3DPY-27uRgpE-XcJuma-gsBszk-ntZjsU-HLtPwp-eks29S-7vDbrT-GSFPoQ-2bCC99q-WTc541-fwVEsq-JbqFYC-22tHBHc-KjBAM-NPShvH-kWuKWa-vuqSLq-kWvrc2-27kRaT8-nxNRJM-PWc1bw-7dSz5D-uxbPSs-t6wRnk-JeYNpQ-rHmqYJ-uo3mRi-HeYsAJ-PYUuZD-PdYw9U-NEj9dp-GTFZut-se3Ctc-wnnbhD-veLT3d-6zmaDJ/*

In the 145 million years since the evolution of flowering plants, highly specialized adaptations for efficient and effective pollination have arisen. For example, the honey bee body has a slight electrostatic charge, which attracts pollen grains to their bodies. Honey bees have bifurcated setae (i.e. branched hairs) covering their body, which helps to hold on to pollen grains. They also have scopae (singular = scopa), which are dense tufts of hair (in leafcutter bees or sweat bees) or depressions on their hind legs (also known as corbicula, in bumblebees and honey bees) that allows them to pack and transport large numbers of pollen grains on their body. Because female bees collect pollen not only for themselves, but also to provide food for their larvae, the scopae of females bees is much more developed than on males.

Honey bees are arguably the most famous of the insect pollinators. Currently, they are used to pollinator over 100 commercial crops in North America. Honey bees are a popular choice for crop pollination because they can be managed to meet crop needs. Although the natural nesting habit for honey bees is in tree hollows, they have been domesticated to nest in artificial hives. These hives can be transported to crop fields, during critical pollination periods. The pollination services offered by honey bees are so valuable, that most commercial beekeepers make the bulk of their money by renting hives to growers, rather than from honey, beeswax, or other hive products.

However, honey bees are just one of the estimated 4,000 species of bee that can be found in North America. Many crops require buzz pollination, and honey bees may not be the most efficient pollinator ; instead, bumblebees, carpenter bees, and leafcutting bees (most of which are native bees, and all of which can perform buzz pollination) are expected to be better pollinators for crops in the genus *Solanum*(e.g. tomatoes, eggplant) and *Vaccinium*(e.g. blueberries, cranberries). In Oregon, especially in the Coastal Regions, we have many species of native bees better adapted to the climate and pollination in windy/rainy weather, making them a better option for many of the*Vaccinium* crops.

About 70% of North America's native bee species nest in the ground. An estimated 30% of native bees nest in wood tunnels, pithy stems, or other cavities. Brush piles, rock piles, and even old rodent burrows can serve as nest sites for bee species. Often, there is little known about these solitary ground nesters, including phenology, basic biology and even identification of species. As a result, it is difficult to understand the economic impact of these organisms on production, and difficult to make a case for the protection of these species.

Figure 8-3: *A Hover Fly, common pollinator in the early months of spring. (Diptera: Syrphidae). Image source: https://en.wikipedia.org/wiki/File:Hoverfly_January_2008-6.jpg*

Ground nesting, solitary life history strategies, annual nests and generally cryptic behaviors make it difficult to both suppress crop pests but protect crop pollinators. Often, the management method that suppresses a crop pest (such as tilling, or pesticide use) can harm or kill insect pollinators. In addition, many crops are planted in large monocultures, which may not provide the variety that pollinators need for a healthy diet. Additionally, most pollinator protection plans focus on bees and butterflies (the latter being an inefficient pollinator), overlooking other important pollinators like beetles and flies. We have only recently started to evaluate the pollination contributions of hover flies (figure 8-3), insects emerging in the very early spring with a big impact on early-flowering plants. However, the loss of natural areas to urban and agricultural development can reduce available forage for all of these pollinators, as can the broad scale control of weeds.

Despite these challenges, pollinator protection can be incorporated into integrated pest management plants, to meet crop production goals while protecting this important natural resource. There are simple steps that farm managers can take, to help protect pollinators.

Pre-Lab 8: Pollinators

Name: ______________________________

Part I. Pollinators (Refer to Week 8 Reading unless otherwise provided).

1. How many species of bees are there in the US and Canada?

2. What is the estimated economic contribution of native pollinators in U.S. crops? And Oregon (find a resource, cite)?

3. Why is there so much difficulty in finding the information to properly answer #2?

4. Name three orders of insects that behave as pollinators in the Pacific Northwest, giving a specific example of each.

5. What is the difference between Acute toxicity, Residual Toxicity and Extended Residual Toxicity?

5. What steps could farm managers take to improve habitat for bees or to otherwise protect pollinator health? Describe three.

Part II.

Pollination is a mutually beneficial interaction between host plant and pollinator, but no matter how perfect the symbiosis, cheating always evolves.

For example, consider the flower *Helicodiceros*, the Dead-horse Arum. This is an example of one way plants can trick insects into helping reproduction while providing no reward.

1. What specific adaptations does this plant have to encourage insect activity?
2. What insect is the target for this flower?
3. How does the plant benefit, and why is this an example of "cheating"?

8. What is Pouyannian Mimicry? Give an example of this type of mimicry that is impacting the evolution of bees.

Lab 8 Assignment: Identification Workshop

Name: ___________________________________

Family Identification: List three insects you were able to identify to family, get them checked as you go:

Order: ________________________________ Family: _________________________________
Check:

Order: ________________________________ Family: _________________________________
Check:

Order: ________________________________ Family: _________________________________
Check:

WEEK 9: THE HUMAN BODY BIOME

Week 9 Materials

Reading

Week 9: Reading ..... [WEB]

Pre-lab 9 Download

Pre-lab 9 .... [WEB][PDF][WORD]

Lab 9 Assignment Download

Lab 9 Assignment ... [WEB]

Week 9: Reading

The Human Body Biome

Arguably, the most dangerous organism to mankind is a tiny Dipteran: the tiny mosquito (of which there are several species globally), are responsible for vectoring many diseases. One of the diseases vectored by mosquitoes, the protist that causes Malaria, is responsible for approximately one million human deaths each year, and infecting around 10% of the total human population each year. The mosquito is not alone: there are many other Diptera species that will feed on the blood of other organisms, and more insects in other orders as well (a few common ones listed at the end of this section).

The Diptera are divided into three sub-orders: the Nematocera (long-horned flies), the Brachycera (short-horned flies), and the Cyclorrhapha (the aristate flies). The "horn" refers to the length of the antennae, though it's important to note that both the Brachycera and Cyclorrhapha have short antennae – the Brachycera have stylate antennae instead of aristate (this might be a good time to review antennal structures and shapes).

Sub-Order Nematocera

Mosquitoes belong to the family **Culicidae** (figure 9-1). Females of mosquito species are the blood-feeders, seeking out prey by following CO2 plumes from exhaled breath, the scent of lactic acid and other cues. Females can feed on several different hosts of different species, and once engorged, stretch receptors in the abdomen trigger egg maturation using the nutrients gained. As a result, a well-fed female can experience more frequent reproductive events, laying a few hundred eggs each event. The eggs are usually laid in wet or moist conditions, and can survive drying regimes as long as 8 months until water returns, triggering hatch (the larvae and pupae cannot survive without water). In general, male mosquitos do not blood feed (in nature) because they lack the proboscis structure capable of penetrating the skin to blood-feed, thus consuming mostly nectar for sustenance.

Figure 9-1: *Only female mosquitos feed on blood. Males lack a proboscis capable of penetrating skin. Image source: https://pixabay.com/photos/mosquito-female-aedes-albopictus-1332382/*

Though mosquitoes are prey for many predatory species, there is no evidence that they are vital to any one ecological system for nutrient and energy transfer – most predatory species feeding on mosquitos have a wide range of prey species available. In addition, the "mosquito eater" or "mosquito hawk" as it commonly called (figure 9-2) does not feed on mosquitoes at all. Another Nematoceran, these crane flies belong to the family **Tipulidae**, and as adults have atrophied gut parts. They do not feed as adults at all.

Figure 9-2: *Commonly known as "mosquito eaters" or "mosquito hawks," the Crane Fly (Tipulidae) does not feed on mosquitos at all. Image source: https://www.flickr.com/photos/livenature/4374686048*

There are several families that can be folded into the general designation "midges" (common name), and of these there are a few that will feed on human blood, animal blood, and the hemolymph of other arthropods and insects. The exceptional family in this regard are the **Chironomidae** (figure 9-3), which although can be a pestilence due to sheer number in areas of synchronized emergence, do not pose a human health risk as biting insects. The common name "no-see-ums" usually refers to midges in the family **Ceratopogonidae**, insects known for causing several itchy bites that don't rise or becoming irritating for hours following the actual bite. The salivary elements of these insects and the number of bites accumulated have caused reactions that persist for weeks on end, headaches and even symptoms of vertigo that persists for days on end. Because of their small size, black flies (family **Simuliidae**) are sometimes confused as midges; though these are in the sub-order Nematocera, they are more robust in appearance and not part of the general group of midges.

Figure 9-3: *Insects in the family Chironomidae does not pose a health risk to humans as they are not a "biting" insect. Image source: Image source: https://www.flickr.com/photos/livenature/4374686048*

Sub-Order Brachycera

Hippoboscidae are a family of blood-feeding parasites that usually plague only livestock in high numbers, but can be detrimental to milk production and vitality so much so that young can die of the induced stress. There are species both winged and wingless in this family, generally referred to as "keds" (figure 9-4), and each species is host-specific. A deer ked may bite a human and feed on blood, causing and irritating rash at the site, but deer keds cannot complete their lifecycle on human blood – they require blood from a deer.

There are several additional species in the **Tabanidae** family, generally referred to as "Horse Flies" or "Deer Flies" (figure 9-5) that are less specific to the species. These flies can deliver a very painful bite – not nearly as subtle as the delicate proboscis of the Nematocera, but instead using a saw-like mouthpart to penetrate the skin. In many species, the saliva contains an enzyme that behaves as an anti-coagulant, causing the host to bleed freely while the secondary mouthpart, the labellum, is used as a sponge to ingest the blood.

Figure 9-4: *A member of the family Hippoboscidae, also known as "keds." Image source: https://commons.wikimedia.org/wiki/File:Hippoboscidae_(17155055946).jpg*

Figure 9-5: *Members of the family Tibanidae, also referred to as "Horse Flies" or "Deer Flies" produce a painful bite in order to feed. Image source: Image source: https://commons.wikimedia.org/wiki/File:The_Amazing_Eyes_of_a_Horse_Fly.jpg*

Sub-Order Cyclorrhapha

Members of this sub-order also have a simplified labellular mouthpart, but though few are biting/feeding on humans as adults, they can cause discomfort through the spread of waste and disease, like the common house fly in the family **Muscidae**. Not only are these notorious for the spread of diphtheria, dysentery and even plague, but their affinity for decay can be problematic for other reasons. For example, forensic scientists attempting to determine cause of death based on blood spray patterns can find confusing traces of blood where flies have waded through wet material and spread it to other locations.

Also notorious for their affinity for decomposing meat, the larger **Calliphoridae** flies are typically the first visitors to a carcass, the adults flying in to lay eggs in the meat within minutes (figure 9-6). These are the most common flies used to establish time of death in forensic science, though they aren't only about dead food materials. Calliphorid maggots have enjoyed somewhat of a resurgence for use in medical debridement procedures, as they can rapidly remove dead and dying tissue thus stimulating new growth and healing. The saliva of these species contains natural antimicrobials to protect the feeding maggots, and thus, medical maggot debridement tends to keep wounds clean.

Figure 9-6: *The Calliphoridae flies are the first to arrive on a decomposing carcass, laying their eggs within minutes of death. Forensic scientists can observe the stage of development of these flies to determine a time of death. Image source: https://commons.wikimedia.org/wiki/File:Calliphora_sp_(larvae).jpg*

A closely related family, the **Phoridae**,include one species commonly referred to as the "coffin fly". Like the Muscids, *Megaselia scalaris* is often found where refuse and decay abound. There are many practical uses for this species: first, they are used a indicators of neglect or abuse, unsanitary care conditions in places like orphanages and nursing homes; second, these insects can help forensic scientists locate crude burial sites, even in cases where the inhabitant of the "grave" has been buried for several months. These flies are so adept at finding resources that they can find sites where carrion has been buried several feet below the ground and actually prefers carrion in advanced stages of decay.

Common Non-Dipteran Feeders: Siphonaptera (Fleas), Bed Bugs (Heteroptera: Cimicidae), Kissing Bugs (Heteroptera: Reduviidae), Anoplura (Sucking Lice)

Insect Stress

There are other ways for insects to behave as a human stress factor besides feeding on blood and tissues – there are a multitude of biting, stinging insects that often surprise and disrupt typical human activities. This has not escaped the attention of especially enterprising humans over the ages, and as a result the tendency for unpleasantness with these types of insects has been capitalized upon for reasons of war and retribution.

One of the first methods of waging war involved the hurling of bee hives at the enemy, and our technology utilizing insects are tools of war has evolved greatly. For example, during World War II the notorious commander Shiro Ishii was responsible for the deaths of over 3,000 Chinese captives, lost to his insane "experiments" attempting to harness insects as vectors of disease that could be mass reared and released on enemy forces – specifically, fleas carrying bubonic plague.

Unfortunately, Ishii hasn't been alone in history in his endeavors, and indeed the US has a medical command installation at Fort Detrick, where a great deal of research concerning potential bio-warfare agents are studied and developed. These agents included diseases caused and vectored by everything from bacteria to insects and rodents.

Not all of the work involving these pesky species is meant for the offensive, however; there is also ongoing research and rapidly-advancing technology that could stay the effects of one such biological attack on the U.S. One of the more prevalent programs has developed Sterile Insect Techniques (SIT) with applications that are broadly meaningful. SIT programs create massive numbers of sterile male insects, like male mosquitos, that are released into local breeding populations to compete for the females as mates. Females mating with the sterile males produce no young, and in areas where these programs have been utilized over the last 10 years, we've seen drastic reductions in populations. With the decrease in mosquito populations, there is a much better chance of containing the spread of mosquito-borne diseases. With advances in this field, it may become possible to harness this technology to also better manage agricultural pests.

For further reading on this subject:

Jeffrey A Lockwood. **Six-legged soldiers: using insects as weapons of warfare**. 2009. Oxford University Press Inc; New York.

Pre-Lab 9: Human Body Biome

Name: ______________________________

1. Name two different Diptera that transmit multiple diseases, listing two diseases for each.

2. Name an insect that will feed on both living and dead human tissues.

3. Name a non-fly that will bite a human but does not spread disease.

4. Give an example of an insect that has been developed as an instrument of war – describe.

Lab 9 Assignment: Collection Register

Name: ____

Input each specimen with the Order and Family name, and check for curation and label completeness. Indicate (X) which specimens have an extra label for sex, ecology, caste, lifestage (list "matched" specimens in sequential rows) under "Extra Label".

Specimen No.	ORDER	FAMILY	PINNED/ VIALED	LABEL 1	LABEL 2	EXTRA LABEL
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
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INSECT COLLECTION

ENT 311: Collection Requirements

[DOWNLOAD PDF][DOWNLOAD WORD]

General Instructions

Over the 10-week progression of the term, you will collect and preserve specimens to create a collection that will be turned in at the end of the term for a significant portion of your lab grade. You will be given the tools to complete the collection, and we will have at least one day in class to collect as a group, and several days where time will be permitted for you to work on your collection with the aid of the lab instructor.

As you collect, you must take notes on the location, date, time, and ecological system in which you catch each specimen.

At the start of each week, you will be expected to bring in three new specimens and the associated field notes. It may be helpful to collect your notes in a single pocket-sized notebook; this information will be used to create the labels for your specimens.

Collection Requirements

- 25 individual families must be collected and correctly identified
- Field notes on each specimen will be recorded at time of collection
- Each specimen is to be properly curated with correct labeling

Grading

For each specimen in the collection, one point each will be awarded for correct Order ID and correct Family ID. One point will be awarded for each correct label as well, for a total of 4 points possible per specimen. Total points possible for the collection is 100 points.

Students may earn extra points per specimen by including a third "Applied" label noting ecological/life history information. This can denote gender (ONLY if externally discernible), separate life stages (up to three), parasitoid/prey relationships, caste (Hymenoptera and Isoptera only), and mimicry (must have mimic and model). For example, a collection may receive credit for two Dermaptera: Forficulidae specimens if they are labeled correctly as male/female, even though both specimens are the same family. At least TWO specimens with differing applied labels must be presented for the extra points.

Accepted Applied Labels

Gender: Male/Female
- Life Stage: Eggs/Immature larvae/Mature Larvae/Pupae/Adult
- Trophism: Prey/Parasitoid (must identify counterpart, i.e. Prey (of Braconidae); Parasitoid (of Aphididae))
- Caste: Worker/Reproductive/Soldier
- Mimcry: Mimic/Model (must identify counterpart, i.e. Mimic (of Apidae); Model (for Syrphidae)).

Correct Labeling

The applied label should be placed below the other two required labels (refer to Week 1 Reading). You will not be awarded extra points without the third label.

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Recommended Citations

APA outline:
Source from website:

- (Full last name, first initial of first name). (Date of publication). Title of source. Retrieved from https://www.someaddress.com/full/url/

Source from print:

- (Full last name, first initial of first name). (Date of publication). Title of source. Title of container (larger whole that the source is in, i.e. a chapter in a book), volume number, page numbers.

Examples

If retrieving from a webpage:

- *Berndt, T. J. (2002). Friendship quality and social development.* Retrieved from insert link.

If retrieving from a book:

- Berndt, T. J. (2002). Friendship quality and social development. *Current Directions in Psychological Science*, 11, 7-10.

MLA outline:
Author (last, first name). Title of source. Title of container (larger whole that the source is in, i.e. a chapter in a book), Other contributors, Version, Number, Publisher, Publication Date, Location (page numbers).

Examples

- Bagchi, Alaknanda. "Conflicting Nationalisms: The Voice of the Subaltern in Mahasweta Devi's Bashai Tudu." *Tulsa Studies in Women's Literature*, vol. 15, no. 1, 1996, pp. 41-50.
- Said, Edward W. *Culture and Imperialism.* Knopf, 1994.

Chicago outline:
Source from website:

- Lastname, Firstname. "Title of Web Page." Name of Website. Publishing organization, publication or revision date if available. Access date if no other date is available. URL .

Source from print:

- Last name, First name. *Title of Book*. Place of publication: Publisher, Year of publication.

Examples

- Davidson, Donald, *Essays on Actions and Events.* Oxford: Clarendon, 2001. https://bibliotecamathom.files.wordpress.com/2012/10/essays-on-actions-and-events.pdf.
- Kerouac, Jack. *The Dharma Bums.* New York: Viking Press, 1958.

Versioning

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Version	Date	Change Made	Location in text
0.1	MM/DD/YYYY		
0.11	10/09/2020	Links to external sources updated	All
0.12	05/24/2021	Links to external sources updated	All