Entomology

Entomology

Lab Manual for UNBC BIOL 322

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Introduction

This is the lab manual for the University of Northern British Columbia's third-year Entomology course, BIOL 322. Welcome to the course!

The lab manual will walk you through all of the basic principles you need to know to complete the lab for this course. Whether you are completing the lab online, in person, or through some mixture of these delivery methods, you will need this lab manual for **each and every week's lab**.

To complete BIOL 322, you will have to develop and submit an insect collection. Completing this assignment will require the use of **robust and ethical** collection and preservation techniques. You will also gain an understanding of the importance of biological collections and collecting data. The labs will also teach you about insect structure and function, and how these influence insect biology.

The majority of the labs will focus on how to identify the major orders of insects, and key unfamiliar insects to order, family, or species. You will also learn about the significance of insects in the ecological web and to human society. The majority of this lab manual covers the identification of various orders and families of insects that are **common in northern British Columbia**. I will also mention a few other taxa with which you should be familiar. Some of you may collect additional orders and families, and I will help you to identify those.

****PLEASE NOTE** that the distinguishing characteristics described here may not provide faultless identification of all insect taxa, and should be applied with caution outside this course, and especially outside northern British Columbia.** If you are uncertain about an identification, please let me know so we can figure out what you have found.

PART I

LAB 1: INSECT COLLECTIONS

1. Introduction

Introduction

The first lab for BIOL 322 will help you understand the importance of insect collections, as well as the requirements for the insect collection assignment in this course. Your goals are to

1. be able to explain why properly curated entomological collections are scientifically important
2. understand the requirements for the BIOL 322 insect collection
3. take an inventory of your collecting kit, and explain how to use the various components

The lab should take you approximately three hours to complete. Even though you may have reviewed some components of the lab already over the summer, please read or watch them again, and pay close attention to the details provided. A short quiz will be available when you have finished the lab, so that you can review your understanding.

2. Why Collect Insects?

Why Collect Insects?

One of Darwin's boxes of beetle specimens, collected on his voyage on HMS *Beagle*. The collection still exists, and is still used by entomologists!

Image: Emőke Dénes, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wiki

Many, many species of insects are still undescribed. Identification and description often require examination of fine details.

This beetle was collected by Darwin in Argentina, 1832, during his HMS *Beagle* voyage. The specimen was considered lost at the Natural History Museum in London, but was found again in 2008. The species was later described and named in 2014.

These specimens can last a long time, and they continue to provide information and material for study.

There are some other reasons why collections are important:

- Names can change, so it is important to be able to look at the actual specimens
- Can gain a better understanding of form and function, especially as we …
- Learn more about ecological relationships
- Improve our understanding of distributions, changes
- Aesthetics

e.g. Studies of climate change requires an understanding of baseline distributions in order to determine whether these are changing (or not!).

The Museu Nacional do Brasil held ~ 20 million items (2X British Museum), spread over ~200 years of history.

Paulo R C M Jr., CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

The museum was burned almost completely on Sept. 2, 2018. Its future is now dependent on collecting loans, material from other institutions, photos, notes... The fact is, much of the material is irreplaceable.

Felipe Milanez, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

We have a responsibility to collect and document biodiversity, aspects of which will, one day, be history. We also have a responsibility to do it in a way that will protect that knowledge. Your collections may seem small, but you are a part of that documentation. Take it seriously.

3. Insect Collection Assignment

BIOL 322 ENTOMOLOGY
INSTRUCTIONS AND MARKING CRITERIA FOR INSECT COLLECTION

TEXT: Marshall SA. 2017. Insects. Their natural history and diversity. 2nd edition. Firefly Books Ltd., Buffalo, NY

LEARNING OBJECTIVES: The insect collection assignment will help you

1. become familiar with habitats where insects are found.
2. practice techniques for collecting insects.
3. learn methods for presenting adult insects for display.
4. improve your insect identification skills.
5. contribute to the long-term documentation of biodiversity.

NOTE: The collections will normally remain the property of UNBC. If you would like to keep your collection at the end of the class, please let me know in advance.

REQUIREMENTS: To achieve those objectives, your collection should focus on relatively large, adult specimens. Up to five species or life stages that are normally collected and stored in ethanol, or that are too small to view without the aid of a microscope, may be included in your collection.

The minimum requirements are:

1. at least 30 specimens representing eight (8) or more orders, and 15 or more families (you may submit more than 30 specimens, but you must clearly indicate the 30 specimens on which you want your mark to be based).

2. all of the specimens must be members of the subphylum Hexapoda (no spiders, mites, ticks, centipedes, millipedes, snails, etc.!)
3. a maximum of five (5) specimens may be preserved in ethanol.
4. three (3) or more of the 30 specimens must be identified to the species level (at least tentatively).
5. each specimen must be correctly mounted, preserved and presented
6. each specimen must be correctly labelled
7. field notes must be submitted with each specimen (numbering the specimens is helpful), including when and where the animal was collected, who collected it, and data about habitat, host plant, collecting method, and other pertinent natural history information. A spreadsheet will be provided for submitting this information, but you should keep careful notes in the field as well.

EVALUATION: Each of the 30 specimens will be evaluated, and will be worth a maximum of 5 points. Marks will be deducted for problems with presentation, missing or misidentified orders/families/species, and errors in mounting, preservation, and labeling. The field notes will be allotted 50 points, for an overall total of 200 points.

Collection Assignment DRAFT 2022

LEGAL AND ETHICAL CONSIDERATIONS: **<u>No collecting</u>** may occur in national, provincial, regional, or municipal parks, or on private land (unless you have the explicit consent of the land owner).

Please be discriminating when you are collecting insects. Do not kill specimens unless you plan to use them for your collection. Ensure that you kill insects as humanely as possible. Allow sufficient time to ensure that the insect is dead before pinning. Trading specimens is permitted, but you **<u>MUST</u>**

identify the actual collector on the label (no marks will be lost for traded specimens), and provide genuine collecting data.

SAFETY POLICIES: In this course, you will be required to participate in an independent project collecting insects. This will require working outside. You are responsible for preparing yourself for any safety issues that you may face. You must also be familiar with and accept the University's Student Responsibility Statement (reproduced below) – it is implied that by participating in this course you agree to these terms.

The following is a list of the possible safety issues associated with doing field work in and around Prince George (taken from UNBC's "Fieldwork – Informed Consent, Agreement to Abide by Rules of Safety").

- Injuries associated with working in managed and unmanaged forests of all ages and types
- Injuries resulting from traversing over uneven or wet terrain with slip, trip or fall hazards
- Injuries resulting from contact with obstructions, projections or falling objects while travelling on foot
- Injuries resulting from overexertion, pre-existing illness or medical condition
- Risk of attack from wild or domestic animals
- Limited emergency medical service, including ambulance service, or a possible delay in communicating an emergency
- Changes in weather conditions
- Hypothermia
- Loss or damage to personal property

This list is generated with the assumption that you will simply be walking on trails and other areas near Prince George in search of insects, and is not comprehensive. **<u>You are responsible for identifying potential risks within your individual study situation, including any that are not listed</u>**.

I recommend that you carry a cell phone, and make sure someone knows where you are going and when you will be back (typical sign in procedures). If getting to sites for insect collection involves driving to sites, you are responsible for making sure you know road conditions prior to departure and are prepared for poor weather driving. If you perceive risks to be too high to safely work (e.g. extreme cold/hot temperature, high wind in forests, icy road conditions), you are responsible for delaying or making alternate arrangements for work. As a result, **do not leave collecting until the last minute, as this could cause you to attempt data collection in questionable circumstances just to meet deadlines.**

University's Student Responsibility Statement

Students are responsible for informing themselves of the risks associated with field and laboratory studies. By participating in such studies they shall be deemed to have accepted personal responsibility for all such risks (including without limitation, all risks identified by course instructors/supervisors that has otherwise been made available to students), to have agreed to abide by the safety rules and procedures established by their instructors/supervisors for such activities, and to have waived the liability of the University of Northern British Columbia and its instructors/supervisors in respect of such activities.

MATERIALS: The following equipment and materials will be signed out to students at the beginning of the term. You may approach the instructor to sign out materials earlier, but this is not necessary. Materials will need to be returned to UNBC following completion of the collection (pins, paper, labels do not need to be returned).

- 1 display box
- 1 insect net with instructions
- 1 shipping box

- 150 insect pins (#0, #1, and #2)
- 1 spreading block
- 1 pinning block
- 1 container of paper strips (for spreading winged insects)
- 1 container of paper points (for mounting small insects)
- 1 16X magnifier
- 1 pair soft forceps
- 5 empty film canisters
- 5 vials of ethanol
- 1 sheet of 100 blank labels

COLLECTING AND PRESERVING: Insects can be collected almost anywhere! Your collecting kit includes a collapsible net (for terrestrial sampling), and a number of small containers to get you started. Be creative – insects are small, so can be found in relatively small patches of suitable habitat. The textbook (Chapter 14) contains basic instructions for collecting insects. More detailed instructions can be found online, *e.g.*,

http://www.entsocalberta.ca/guide.pdf or
http://esc-sec.ca/wp/wp-content/uploads/2017/03/AAFC_insects_and_arachnids_part_1_eng.pdf.

You will obtain the best result by using large, sturdy specimens. All soft-bodied insects (aphids, caterpillars, aquatic nymphs) must be preserved in ethanol. There will be enough time to meet the requirements at the start of the fall term, so collecting during the summer is not essential for an excellent grade on the collection, but it gives you more options.

It is easiest to collect insects in plastic film canisters (transparent containers are recommended) or other non-breakable containers, and to **freeze them for killing and storage**. Keep the specimens frozen until you are ready to mount them. A chest freezer is ideal, but a fridge freezer will also work. Moths and butterflies should preferably be dealt with relatively fresh, but can be preserved frozen if the collection vial is wrapped in moist paper towel, and placed in a plastic bag. This will aid in preventing freezer burn (desiccation), which essentially makes the specimen very brittle. It is recommended that you collect moths and butterflies near or after the start of the term, however, or contact your instructor for help with mounting them. **All specimens, except those preserved in ethanol, should be kept in the freezer until you are ready to pin them.** Once thawed, which takes only a few minutes, each specimen should be pinned **promptly**, and set at the correct height on the pin immediately. Any adjustments to the positioning of various body parts **must** be completed before the insect dries out. Once the specimen has air-dried, do not attempt to adjust it any further, and handle it only by the pin.

MOUNTING: You will learn how to mount and present insects in the first two weeks of the course. Each insect must be thawed (it only takes a few minutes to thaw a small insect!) and then completely mounted **while it is still flexible**. Once it has air-dried, you will be unable to adjust its position on the pin, or to move wings or other appendages, without causing serious damage to the specimen. If you are interested in learning some of the mounting techniques ahead of time, there is good information available from various online sources, *e.g.*

http://www.entsocalberta.ca/guide.pdf

http://esc-sec.ca/wp/wp-content/uploads/2017/03/AAFC_insects_and_arachnids_part_1_eng.pdf

https://entomologytoday.org/2013/10/18/videos-on-how-to-pin-insects/

https://www.youtube.com/watch?v=QFG4ri7AiP0

https://extension.oregonstate.edu/sites/default/files/documents/9591/pinning-insects.pdf

Note that some information you find online may be inappropriate for the purposes of this collection. For example, dragonflies are often preserved with wings folded to save space: you will be mounting them with wings spread. When in doubt, check with your instructor.

LABELING: Every specimen should have label data included with it, inside the storage container, at all times! Do not assume that you will remember where/when you collected each one – write it down on a scrap of paper right away and keep it with the specimen. Writing on the outside of containers, or taping a label to the outside of the container is NOT a good practice, as the data can easily become separated from the specimen.

For the final collection, minimum labeling (location, date, collector) information is required, while secondary labels (habitat, plant, trap etc.) are optional (but strongly encouraged). See http://www.biology.ualberta.ca/bsc/pdf/labelbrief.pdf for more information on label standards. Labels are made of archival grade paper, and are best **hand-written in pencil**. Some blank labels are included with your kit: they are 17 mm long by 6 mm wide. Pro tip: write on the labels before cutting them out and separating them from the sheet! It is also possible to print labels using a 3-4 point sans serif (*e.g.* Arial, Calibri) font, but they must be printed on archival paper using a laser printer (not an ink jet). The sheet of labels should then be ironed gently with a clothes iron to improve the adhesion of the print to the paper. Proper printing is especially important for specimens preserved in ethanol. Contact your instructor for more information.

Example text, 1^{o} label

CAN:BC:Prince George, Hudson Bay Slough *Notice that Prince George is NOT abbreviated*

[UTM or lat and long coordinates] *Strongly preferred, but not required for this course*

2016/VII/15 *Note that the month is written in Roman numerals, and the year is written in full*

LM Poirier *Name of collector – see note about trading above*

Example text, 2^{o} label

Under rock, edge of pond

A species label is normally provided for collections; you will require one for three (3) specimens.

Example species label

Dendroctonus ponderosae Hopkins

Det. LM Poirier *Name of person who identified the specimen*

4. Collection Examples

Note that it is helpful to organize your collection taxonomically. A number attached to each specimen also ensures that it will be simple to associate each specimen with
the corresponding field notes.

Insect collection examples

5. What's in My Kit (and what do I do with it)?

What’s in My Kit (and what do I do with it)?

This presentation will give you a tour of the insect collecting kit you have received, including a brief introduction to the uses for the various components.

Other demonstration videos and links will provide further information about using your kit to collect, prepare and preserve insects for your Insect Collection assignment (worth 20% of your grade for BIOL 322).

When you receive it, your kit should look something like this.

Most of the components will be inside the black box, but the spreading board and the three parts of the collecting net will be separate.

The black box itself is called a display box. Notice that the bottom is lined with a high-density foam.

Once your insects are mounted on pins, you will be able to push the pins into this foam bottom to organize and display your specimens.

Also included is a smaller box, called a shipping box, which also has a foam-lined bottom. Note that the lids are often very tight on these boxes, as they are intended for mailing specimens.

For your collections, the shipping box may be useful for sorting specimens, for protecting them while they dry, and for various other purposes.

Your insect collecting net comes in three pieces: one with the actual collapsed net, one long tube with a red handle on one end, and one long tube with no handle.

You will need to assemble this into a single net.

To begin with, carefully unwind the net and let it expand.

The frame of the net is a springy, metal ring, which collapses when it is twisted (more on this later).

When you are expanding the net, please do it carefully, and don't let the net frame hit anything (especially your face!) as it expands.

There is an excellent video on YouTube, https://www.youtube.com/watch?v=axaZAlXA0u0, (and a rather less excellent one in the lab materials!) that explains how to expand and collapse the net.

Next, you can assemble the net handle. The pieces fit together much like the pieces of a vacuum cleaner tube.

The piece without the red handle attaches to the net frame, and the piece with the red handle is attached to the end of that assembly.

You should end up with a net that looks more or less like this, with a long handle and an expanded bag.

You may disassemble and collapse the net for easy storage and transportation, but please always make sure that it is clean, empty, and dry before you do so.

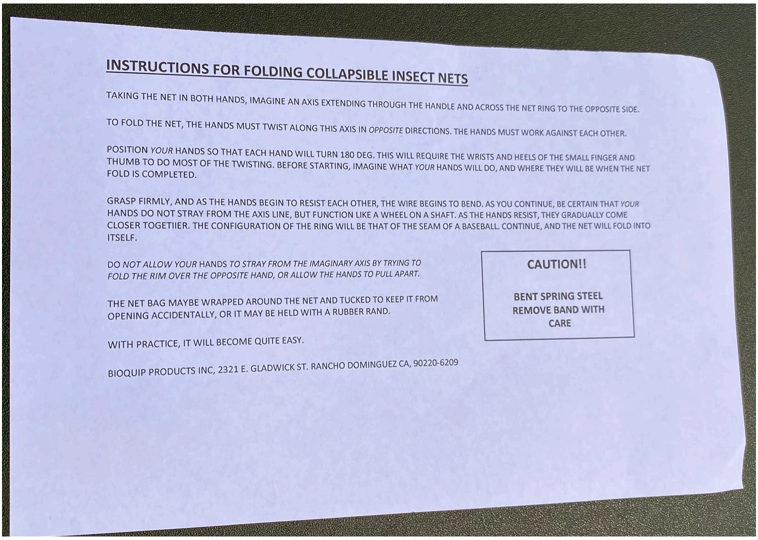
Instructions for folding your collapsible net are included in your kit.

I will also post a short video clip of me doing this.

My tips:

- – be patient
- – don’t force the frame into position
- – practice!

It is a good idea to tuck the end of the net under itself, and/or use an elastic band or other means to hold it in place, so that it doesn’t expand accidentally!



INSTRUCTIONS FOR FOLDING COLLAPSIBLE INSECT NETS

TAKING THE NET IN BOTH HANDS, IMAGINE AN AXIS EXTENDING THROUGH THE HANDLE AND ACROSS THE NET RING TO THE OPPOSITE SIDE.

TO FOLD THE NET, THE HANDS MUST TWIST ALONG THIS AXIS IN *OPPOSITE* DIRECTIONS. THE HANDS MUST WORK AGAINST EACH OTHER.

POSITION *YOUR* HANDS SO THAT EACH HAND WILL TURN 180 DEG. THIS WILL REQUIRE THE WRISTS AND HEELS OF THE SMALL FINGER AND THUMB TO DO MOST OF THE TWISTING. BEFORE STARTING, IMAGINE WHAT *YOUR* HANDS WILL DO, AND WHERE THEY WILL BE WHEN THE NET FOLD IS COMPLETED.

GRASP FIRMLY, AND AS THE HANDS BEGIN TO RESIST EACH OTHER, THE WIRE BEGINS TO BEND. AS YOU CONTINUE, BE CERTAIN THAT *YOUR* HANDS DO NOT STRAY FROM THE AXIS LINE, BUT FUNCTION LIKE A WHEEL ON A SHAFT. AS THE HANDS RESIST, THEY GRADUALLY COME CLOSER TOGETIIER. THE CONFIGURATION OF THE RING WILL BE THAT OF THE SEAM OF A BASEBALL. CONTINUE, AND THE NET WILL FOLD INTO ITSELF.

DO *NOT ALLOW YOUR* HANDS *TO STRAY FROM THE IMAGINARY AXIS BY TRYING TO FOLD THE RIM OVER THE OPPOSITE HAND, OR ALLOW THE HANDS TO PULL APART.*

THE NET BAG MAYBE WRAPPED AROUND THE NET AND TUCKED TO KEEP IT FROM OPENING ACCIDENTALLY, OR IT MAY BE HELD WITH A RUBBER RAND.

WITH PRACTICE, IT WILL BECOME QUITE EASY.

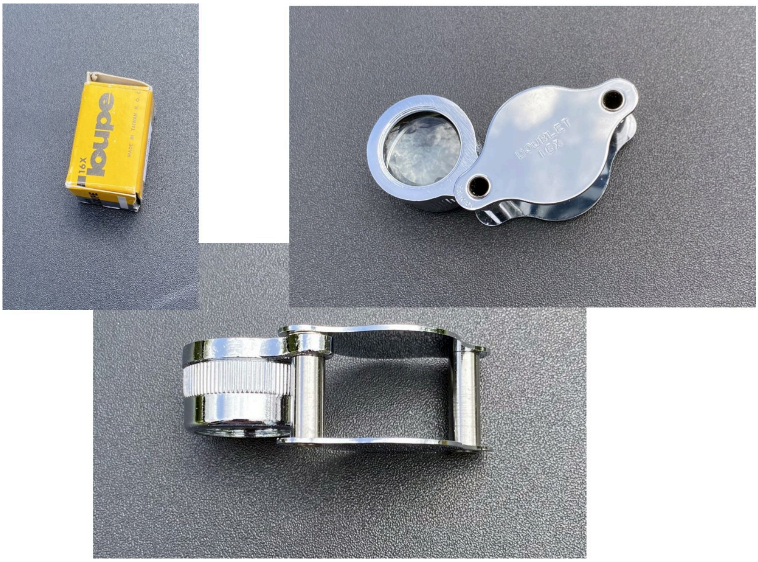
BIOQUIP PRODUCTS INC, 2321 E. GLADWICK ST. RANCHO DOMINGUEZ CA, 90220-6209

CAUTION!!

BENT SPRING STEEL REMOVE BAND WITH CARE

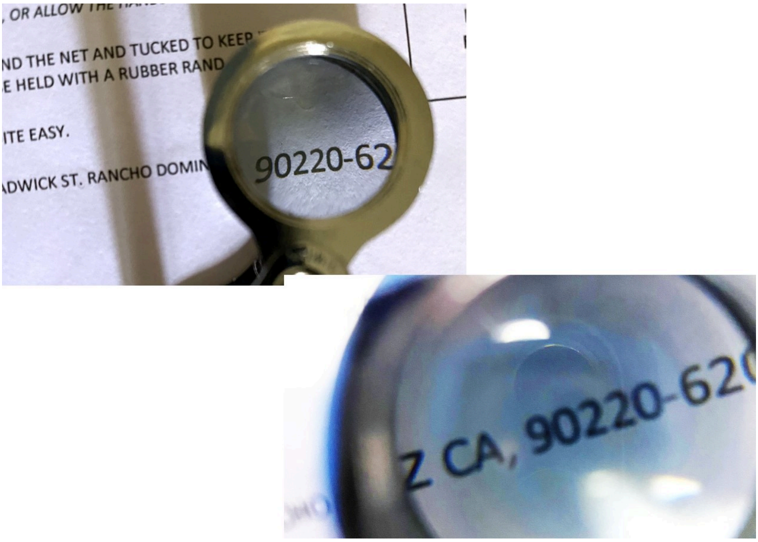
A folding loupe, or hand lens, is included in your kit.

It magnifies at 16x power. Our dissecting microscopes in the teaching labs at UNBC magnify to ~40x or higher.



However … if you have a camera phone, you may be able to improve the magnification somewhat by photographing your insect through the lens, and then zooming in on the image.

I don't guarantee this will work, and it may need some image adjustments. It will certainly require creativity and patience!



Next up are the forceps.

Your kit comes with a pair of soft-touch forceps, which can be useful for handling flexible specimens, and positioning wings and other body parts **before** the specimen has dried.

Once the specimen has air-dried, you will not be able to move any of its appendages or adjust its height on the pin – everything must be adjusted while the insect is still fresh and (reasonably) flexible!

Most adult insects are mounted on entomological pins for preservation and display. The pin allows specimens to be presented in foam-lined boxes, and they can be handled and moved by touching only the pin. Dried insects are extremely fragile, so the pin means you do not need to touch a dried specimen.

Your kit includes three sizes (thicknesses) of pins: 0, 1, and 2. Both larger and smaller sizes exist, but these should be suitable for most of the insects you will encounter. It is very difficult to tell the sizes apart by eye, so be sure to keep your pins separated in their individual containers. The general rule is to use as large a pin as you can without damaging the specimen.

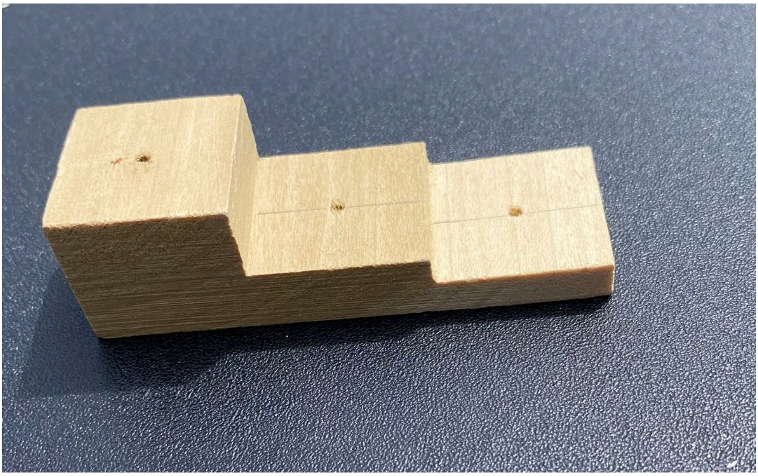
Notice that these are **<u>not</u>** the same as sewing pins! They have special coatings that keep them from oxidizing over time, and a small nylon ball on the top for easier handling.

They are also <u>extremely</u> sharp, so try to be careful not to drop them (especially around pets, family members, or roommates), lose them, or (of course) poke yourself!

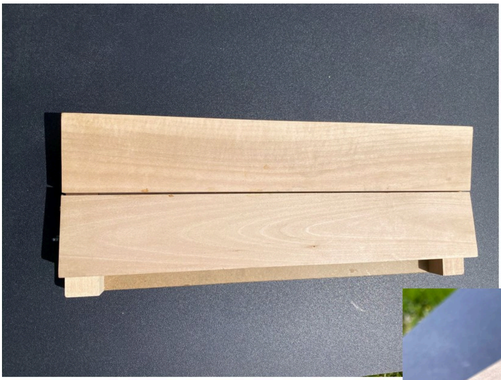
This next little tool is called a pinning block. It is used to help you set the height of the insect and labels on each pin. The pin is pushed through the insect in the correct location (depending on the type of insect – more on that later!). The pinning block is then placed on a flat, hard surface, and the pin is pushed further through the insect and through the small hole on the top level of the block. When the pin goes all the way through the hole, and reaches the hard surface, the insect is set at the correct height. That way, every insect in your collection will be set at the same height on the pin, and will have enough pin showing at the top that you can pick up the pin and move the specimen without ever touching the dried insect.

The exception to this method – if you have a very heavy-bodied specimen, e.g. a bumble bee, you may need to push the specimen a little bit lower on the pin. It is really important to leave enough of the top of the pin showing so that you can handle it without touching the insect!

The lower levels of the block are used to set the heights of the labels that you will include with your collection: the collecting data on the middle level, and the identification label or other information on the third level.



This is a spreading board, and it is used to spread the wings of moths, butterflies, and some other insects. Once mounted on its pin, the body of the insect is positioned in the central groove, which is foam-lined. Notice that the width of the groove can be adjusted, so that it just fits the insect's body, using the nut on either end of the board (please be careful not to lose these parts!). The wings are then spread out on the board surface, and anchored in place with paper and pins until the insect is completely dried. This is a challenging technique, that requires some practice, so I suggest not trying it first on your favourite butterfly specimen! I will supply a short demonstration/video on the technique along with the first lab materials.



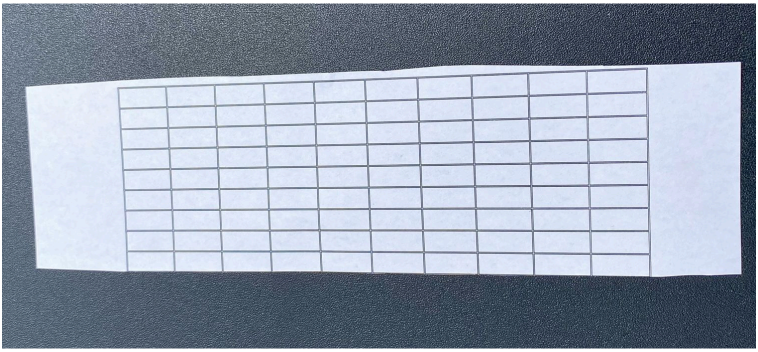
Two other types of mounting supplies are included in your kit: wing paper and points.

Wing paper is used, along with the spreading board, to help anchor wings and other body parts in place. Pinned flat on top of an extended wing, it keeps the wing from curling or moving as it dries in place. It looks much like waxed paper, but isn't. It is glassine paper, which is much less sticky, and removes fewer scales from the wings of butterflies and moths.

If an insect is too small for a size 0 pin to be used without causing damage to the specimen, it should be mounted on a point. Points are small triangles of heavy paper. The pin is inserted through the wider end of the triangle, and the very tip of the point of the triangle is bent down slightly. A tiny drop of glue is placed on the bent-down tip, and the glued part is then touched to the right side of the insect's thorax. The insect should be upright and level in all directions, and will sometimes require creative support (e.g. pieces of paper on pins at the right height) until the glue and insect have dried. There is a fine balance between having enough glue to hold the insect in pace when it has dried, and having too much glue so that the specimen's features are obscured. The nice thing about this technique is that it can be used on specimens that have already dried (but they must be too small for a size 0 pin!).

Your kit also comes with a supply of blank labels, 17 mm long by 6 mm wide. These are printed on archival-grade paper, and are the correct size for insect labels. The handout that provides information about your collection tells you what needs to go on each label, and they should be completed in pencil, not pen.

If you have access to a laser printer, and an iron, I can send you the MS Word template for labels. Other printer inks and media are not archival, and must not be used. That means you are probably going to have to write very, very small in order to fit everything on each label!



Finally, I have included a spare piece of foam and five empty film canisters in your kit.

The foam is useful for holding pins, and pinned insects, as you work on your collections. Pinned specimens can be inserted at various angles, even completely upside down, so that you can see various body parts. Any foam will work, so, if you have some Styrofoam packaging around, feel free to make yourself extra blocks.

The film canisters are getting harder to come by, but they make excellent containers for specimens while you are collecting. Held in one hand, they can be maneuvered up inside the net to catch insects; they can be placed over top of flying insects; insects can be encouraged to walk into them; and they don't break easily in the freezer. Any container you have on hand will do, but these should get you started.

Please feel free to ask me your collecting questions and photos, or share them with the class!

For more information, ask me! or, check out:

http://www.entsocalberta.ca/guide.pdf

http://esc-sec.ca/wp/wp-content/uploads/2017/03/AAFC_insects_and_arachnids_part_1_eng.pdf

https://entomologytoday.org/2013/10/18/videos-on-how-to-pin-insects/

https://www.youtube.com/watch?v=QFG4ri7AiP0

https://extension.oregonstate.edu/sites/default/files/documents/9591/pinning-insects.pdf

6. How to Fold a Collapsible Insect Net

How to Fold a Collapsible Insect Net

Be sure to watch the video of me attempting to fold and unfold a collapsible insect net properly (on Blackboard), or watch a professional do it at

https://www.youtube.com/watch?v=axaZAlXA0u0!

PART II

LAB 1A: PREPARING AND PRESERVING YOUR INSECT COLLECTION

7. Introduction

Introduction

You are now at the stage where you can begin to prepare your insects for submission to the Insect Collection Assignment. You should now thaw the containers one at a time or in small batches. Insects dehydrate and become brittle very quickly, so don't thaw more than you know you can mount at one time.

8. Pinning

Pinning

Once the insect has thawed (this may take ~10-15 minutes, depending on the size of the insect, the temperature of the room, and how cold your freezer is), consider what size pin to use. You have three sizes of insect pin in your kit: 0, 1, and 2. Size 0 is the smallest, and size 2 is the largest. These are coated pins, specifically designed not to rust under normal storage conditions, even though they contact insect body fluids. You will want to use the largest pin you can without damaging the specimen. It may take a few attempts for you to learn how to judge what pin size to use – so do not start with your best/favourite/most unique specimen!

1. Pin Placement

Next, you need to decide where the pin should be placed. Pin placement varies with the order and shape of insect. The goal is to keep at least one side (by convention, the left side) of the insect intact and undamaged, and not to obscure any feature that may be important for later identification. First, then, you're going to decide what order the insect belongs to – if you aren't quite sure, please ASK FIRST! The last page of this summary has a table that should help you decide where to place the pin, and there some examples below – again, if you are unsure or nervous about this step, please feel free to ask me for help.




2. Inserting the Pin

The pin should go into the dorsal side of the insect at the correct location, and pass straight through to the ventral side. Once the pin is through (don't push it all the way through, just enough so the tip of the pin is coming through the ventral side!), the insect should be straight on the pin: it should not look like an aircraft on takeoff, nor should it be doing a nosedive! It should also not be tilted to one side or another. Remember that pinning is an acquired skill – it takes time and practice to learn how to do this well. It may take more force than you expect to push the pin through the insect … sclerotized chitin is tough stuff. Also, mind your fingers! As you push the pin through the insect, you will be pushing it through many different muscles. The insect will move (often in the most awkward way possible, that makes it crooked…), and the legs and wings may even move a little. This does not mean that the insect is still alive; it means that you are pushing on/through muscle.

3. Setting the Insect's Height on the Pin

Once you have the insect on the pin, you should now be able to use the pin to handle the specimen. That minimizes (though it won't eliminate) the chances of knocking off legs, wings, or the head. Now you need your pinning block. Place the block on a hard, flat surface. Hold on to the pin by the head, and put the point of the pin into the hole on the top level of the block. Push down on the head of the pin until it contacts the hard surface beneath. This will set the insect at the correct height on the pin. There should still be enough pin showing above the insect to allow you to hold on to the pin: if you have a very stout insect, e.g. a bumble bee, you may need to push the insect down a little further on the pin. (This is quite acceptable – it is very important to be able to pick up the dry specimen by the pin only, without touching the insect).

4. Adjusting Body Parts

Once the insect is set at the correct height on the pin, you may find that various body parts are droopy, in the wrong position, could look neater, etc. My preferred solution is to use other pins (try to keep track of pin sizes that you use – they're hard to tell apart!), pieces of paper, bits of paper/card on pins, etc. to support various body parts in the position that I want them. You can also push the pin into the small piece of Styrofoam that came with your kit – be careful not to move the insect further up on the pin! – and then use another pin to move the legs/antennae around. There is a tradeoff to this exercise: the more you fiddle with the specimen, the more likely you are to break something or have one of the specimen's body parts fall off. The table at the end of this summary lists the structures you will likely need to identify your specimen properly.

5. Specimen Repair

** "AAAHHH!!! I fiddled too much – can I glue a leg/wing/head back on!!??"

You can, but be very careful!! Make sure the leg/wing/head actually belongs to the specimen … and make sure you glue it back on right side up! Use a tiny amount of white glue to reattach the broken piece. If it becomes a glue-blob with legs sticking out – it's a write-off!

6. Specimen Drying

When you are satisfied, let the specimen air dry for about 7-10 days. It can then be moved – handling only the pin – and relocated into the display box.

One last note: once you have pinned insects in it, **NEVER, EVER** put anything else in the box, especially anything that can slide or roll (this is the voice of experience speaking)!

9. Pointing

Pointing

What if your insect is too small to pin using a size 0 pin? There are smaller gauge pins that you can get, but I have not included them in your kit as they can be difficult to use. Instead, you should “point” very small specimens.

Points are small triangles of heavy paper, made with a special point punch. I have included a small number of points with your kit. To mount an insect on a point, you first mount the point itself on a pin: I like a size 2 pin, but other sizes are acceptable. The pin is pushed through the base of the point (the opposite end to the narrowest angle). The height of the point can then be set on the pin using the top level of the pinning block. Bend the very tip of the point down at a right angle, and apply a small amount of white glue to the bent down tip. Then, touch the glue droplet to the right side (keeping the left side visible) of the thorax of the small insect. Again, you want the insect to be straight in all directions, and stuck on to the point. You may need to support it with other pins, pieces of paper on pins, etc. until it dries.

10. Spreading

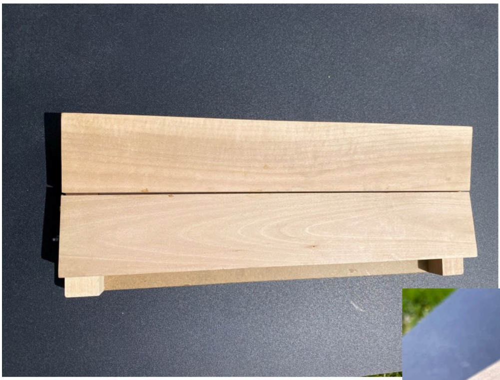
Spreading

For some insects, spreading and flattening the wings makes for a nicer-looking specimen, but it is not necessarily important for identifying the insect. For others, wings are absolutely essential for identification, and you must spread the wings properly. This is particularly important for the Lepidoptera, the butterflies and moths.

To spread the wings of a Lepidoptera, you will use the spreading board provided with your kit. You will also need the wing paper, a pair of scissors, lots of spare pins, a considerable amount of patience, and a steady hand. I recommend starting with a large specimen, preferably one of which you have several examples.

Setting up the Spreading Board

First, pin the specimen through the thorax, and set it to the correct height on the pin using your pinning block. Now, loosen the butterfly nuts on either end of the spreading board. You want the groove in the centre of the spreading board to just accommodate the body of the specimen. Set the groove to the width of the body, and then tighten the nuts again. The pin, with the insect on it, can be pushed into the centre of the groove until the wings, if they were spread out flat, would just rest on top of the board.



Next, you need to convince the wings to flatten. If they are folded straight up above the insect's body, then use a small strip of wing paper to slide between the wings and draw them down to the surface of the board. If they are folded like a tent over the back, you need only spread them out.

Spreading the Wings

The next step is to spread the wings out flat. Your goal is to get the hind margin of the front wings to lie perpendicular to the body of the insect. Start on one side, and use a pin or your forceps to move the wing forward gently until it is in the right position. Use a piece of wing paper to anchor that wing in place (use plenty of pins in the wing paper to surround the wing, but don't put pins through the wing). Next, the hindwing is drawn up so that the front margin of the hindwing just barely overlaps the hind margin of the forewing. Anchor everything in place with wing paper and lots of pins. Don't neglect the outer parts of the wings – they will curl up around the paper as the specimen dries, so make sure they are totally covered with wing paper, and the wing paper is pinned down firmly.

Air Drying

Leave the specimen for 7-10 days to air dry. After that, you should be able to remove the pins and wing paper, pull the specimen out of the groove (handling only the pin it is mounted on), and place it in your collection.

There are helpful videos at the following links, or ask me and I can demonstrate.

https://entomologytoday.org/2013/10/18/videos-on-how-to-pin-insects/

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.bccampus.ca/unbcbiol322/?p=166

11. Common Problems

Common Problems

Here are some photos of insects that have been incorrectly pinned. See if you can tell why these specimens would lose a mark (or marks).

12. Pests of Collections

Pests of Collections

A note about pests … If your specimens are damp, or if you live in a very humid area, fungi can be a problem. The best solution is to make sure that your specimens are thoroughly dry before placing them in your display box.

A bigger problem is insects that eat dead insects! Beetles in the family Dermestidae, in particular, are a major pest of insect collections. If you notice small piles of dust under a pinned specimen, especially a large or heavy-bodied specimen, the best solution is to freeze the entire display box immediately. Dermestid larvae can destroy an entire display box in a few weeks. They are likely to be more of a problem for me than for you (I will freeze all of your collections as soon as I receive them to protect our teaching collection), but can be an issue if you want to keep your collection rather than donating it to UNBC. Mothballs, or their equivalent, can also help, but the fumes are toxic, and they should be used only with appropriate safety precautions. Your best defense is vigilance!

PART III

LAB 2: INSECT ANATOMY

13. Introduction

Introduction

Before you can begin to identify insects to order, family, or genus and species, you will need to develop a vocabulary for the various parts of an insect's external anatomy. In order to understand how insects function and live their lives, you will also need to understand their internal anatomy and a little about their physiology. This lab is designed to help you achieve those goals. Remember that there is a glossary associated with this course (click on "Glossary" on the left-hand menu in Blackboard). If you notice terms are missing, please let me know.

The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can review your understanding.

14. Insect Anatomy - The Basics

Insect Anatomy: The Basics

This week's lab is all about insect anatomy, both external and internal. You will encounter lots of terminology, and you will use it later as you learn how to identify various types of insects.

The model insect that we use for this purpose is the eastern lubber grasshopper, shown below. The female (lower) is laying eggs, while the male (upper) has fertilized the eggs.

In the lab, we use lubber grasshoppers, *Romalea* sp., provided by Ward's Science. They are reared in the lab specifically for educational purposes. Once preserved, they are not this colourful, and the internal structures become more difficult to see.

I have attempted to photograph the key points of the external and internal anatomy, and will highlight the most important structures that you need to know for this course.

You should also watch the video and other links provided with the lab materials.

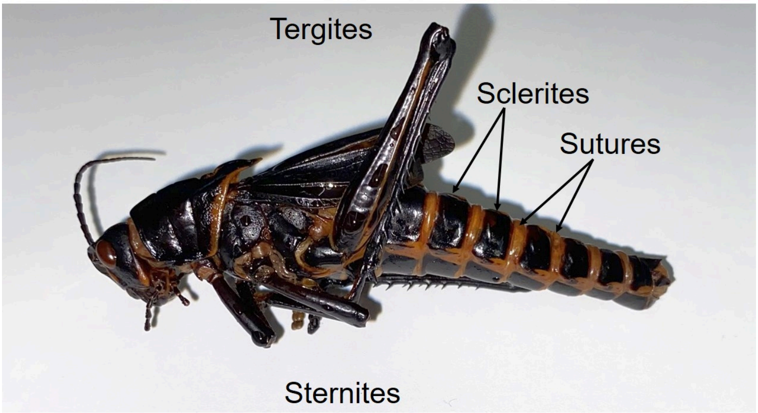
By http://www.birdphotos.com – Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=4021735

External Morphology – The Basics

This is a whole, preserved specimen of a lubber grasshopper.

Notice that the body looks like it is covered in armour plating. This is the exoskeleton of the insect. The plates are called sclerites, and the softer, membranous areas joining sclerites are called sutures.

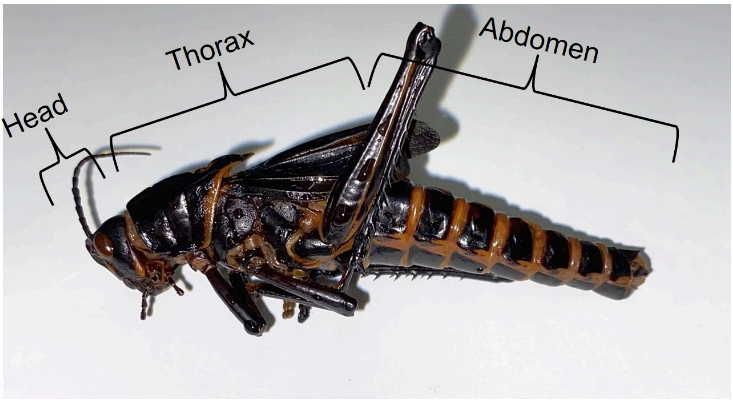
The sclerites on the upper, or dorsal, surface of the animal are called tergites, while those on the lower, or ventral, surface are called sternites.



External Morphology – Tagmata

Note the three body regions, or tagmata (singular: tagma): the head, thorax, and abdomen. The head is specialized for feeding and sensory functions, the thorax for locomotion, and the abdomen for feeding, reproduction, and other physiological functions

We will look at each of these tagmata in turn.

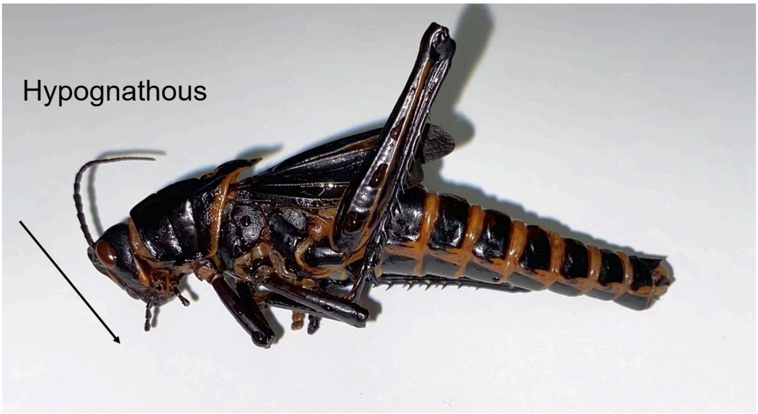


15. Insect Anatomy - The Head

External Morphology – Head

The first of the three tagmata is the head.

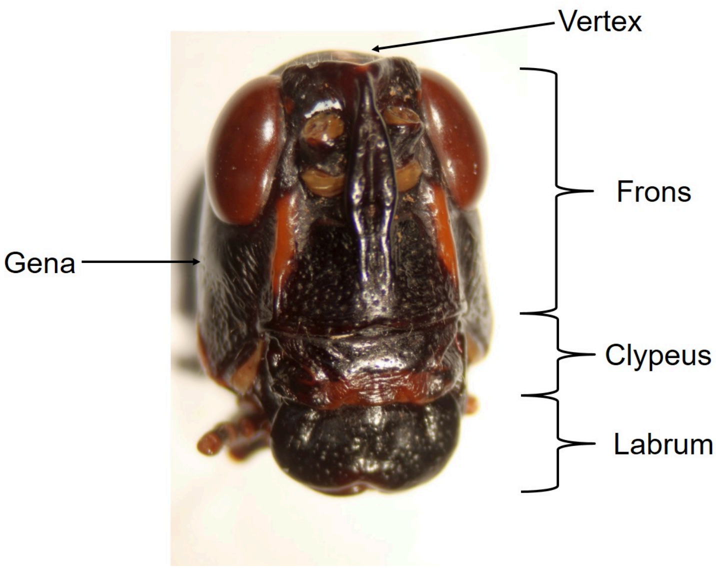
The grasshopper head is oriented with the mouthparts pointing downwards, or ventrally. Thos arrangement is called hypognathous (hypo, below/down; gnath, jaw). Other insects may have mouthparts that point forwards, or even backwards, and you'll see examples of these later on.



Looking more closely at the head, from the front in this next photo, you can distinguish some sclerites (antennae removed for clarity).

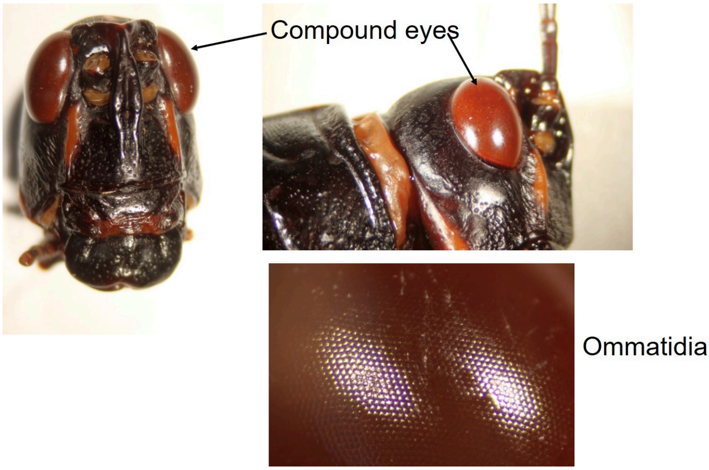
- Vertex – top of head
- Gena ("cheeks") – sides of head
- Frons – front of head
- Clypeus – below frons
- Labrum ("upper lip") – below clypeus

Modifications of these structures can be important for identifying insects.



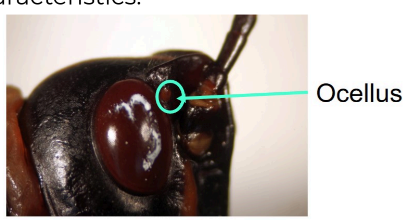
The head, as I said, is specialized for sensory functions and feeding. The major sensory structures visible include the compound eyes, which are located laterally on the grasshopper.

Zooming in on a compound eye, you can see many individual hexagonal facets, called ommatidia. Each one (ommatidium) is an image-forming structure, with the images integrated by the brain into a single image, much as our brains integrate information from our two eyes to make a single image.



Many insects also have ocelli, which are not image-forming, but help to detect light and dark, and may assist with flight.

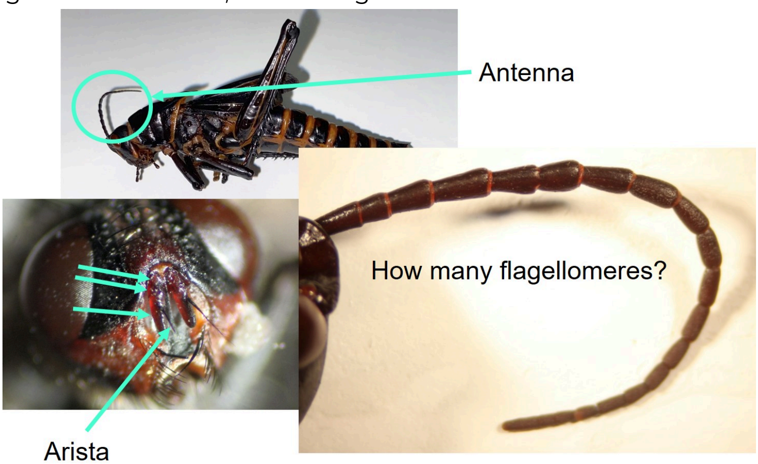
Ocelli are difficult to see on *Romalea*, but are much more obvious on some other insects. Their presence or absence, locations and number can be important identifying characteristics.



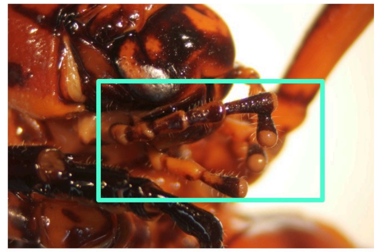
Antennae are important sensory structures, but some stages of some insects may be missing them entirely.

Looking more closely at the grasshopper's antenna, you can see that it is segmented. These segments are called flagellomeres. Identification keys sometimes ask you to count the number of antennal segments. How many do you see on the grasshopper? It gets a bit out of focus towards the tip, but you should be able to distinguish 18.

Antennae can also come in a wide variety of shapes, sizes and lengths. For instance, this fly (bottom left image) has a three-segmented antenna, with a long bristle called an arista.



You may have noticed two pairs of structures associated with the mouthparts of the grasshopper that kind of look like short antennae. These are palps, which are also sensory structures. They are a little easier to see if we zoom in on a ventral view, and will be much easier to see as we dissect the mouthparts.



You have already seen the labrum. Remember that above the labrum is the clypeus, and above that the frons (sclerites of the head).

For the mouthparts dissection, the labrum is the first structure we remove. You will see that the shape varies in other insects.

With the labrum removed, you will see some hard, toothed structures behind it.

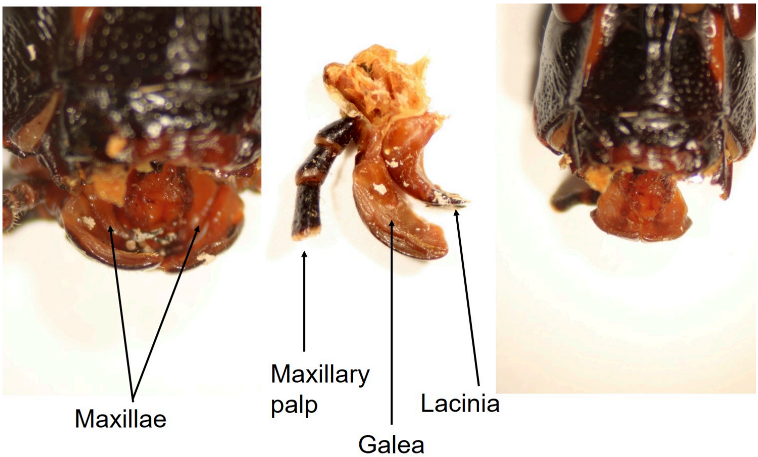
These hard, toothed structures are the mandibles.

When one mandible is removed, you can see that it is heavily sclerotized (hardened), and that it has pronounced teeth on the inner margin. Grasshoppers eat… well… grass! So, why all the teeth? Grasses have lots of silica crystals in the leaves, as a herbivore deterrent, so grasshoppers need tough mandibles to grind up the leaves they eat. Even so, the teeth will wear down over time.

Once the mandibles are removed, you can see more mouthparts behind them – these are the maxillae.

When the maxillae are removed, you can see that each is composed of several parts. In the grasshopper, the galea is scoop-shaped, and the lacinia is pointed, with some sclerotized teeth. The maxillary palp, as you've already is seen, is sensory.

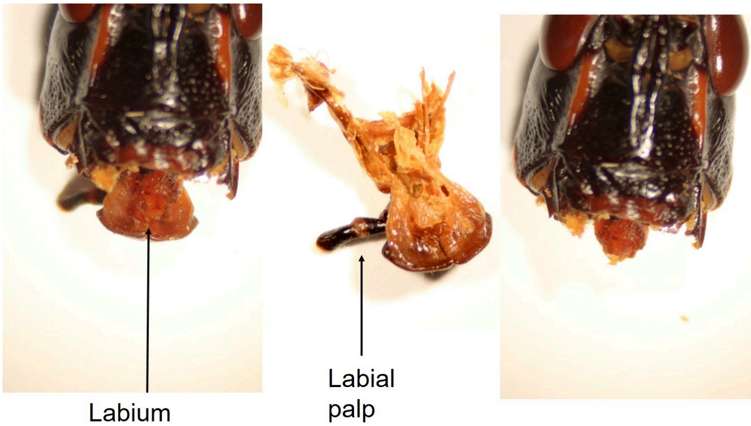
Once the maxillae are removed, you can see the remaining mouthparts towards the back of the grasshopper's head.



At the back of the head is the labium ("lower lip"). Note the similarity in spelling between labium and labrum. Spelling it "labrium" on an exam will not get you a mark for either one!

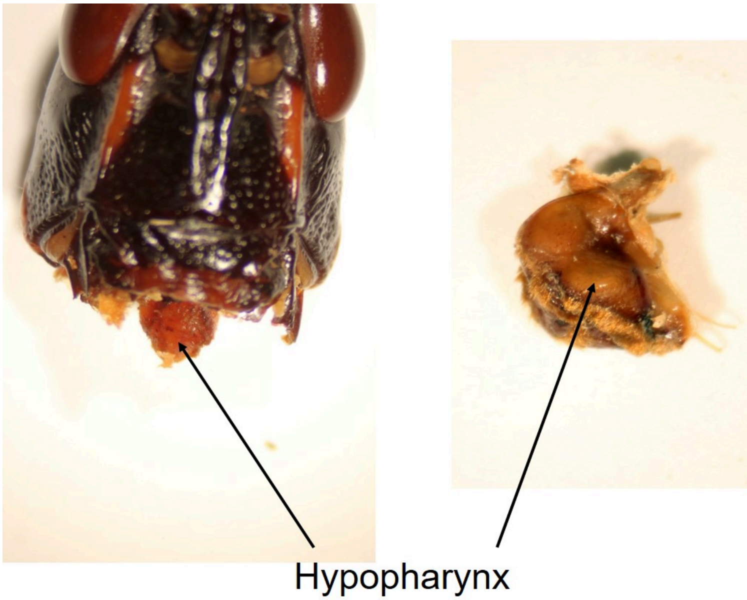
At the top of the photo, notice the muscle fibres that attached the labium to the head of the grasshopper. The two halves of the labium are fused to form a single, median structure, again composed of multiple parts (I'm not going to cover all of those names, though!). There is also a pair of palps associated with the labium, again sensory in function.

Once the labium is removed, there is only a single, central structure remaining.



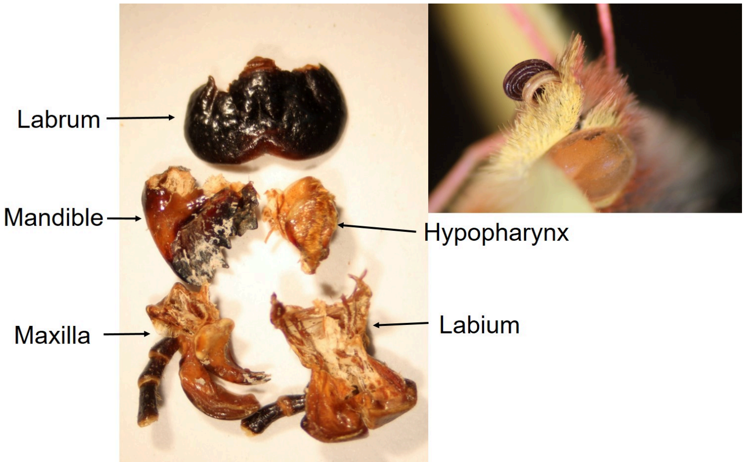
The remaining structure, the hypopharynx, is in approximately the centre of all the other mouthparts you've seen. We have the labrum and mandibles to the front, maxillae to the sides, and labium to the back of the head.

In the grasshopper, the hypopharynx is roughly analogous to our tongue, manipulating food and guiding it towards the esophagus.



Arranged all together, here are the mouthparts, so that you can see their relative sizes and shapes in the grasshopper.

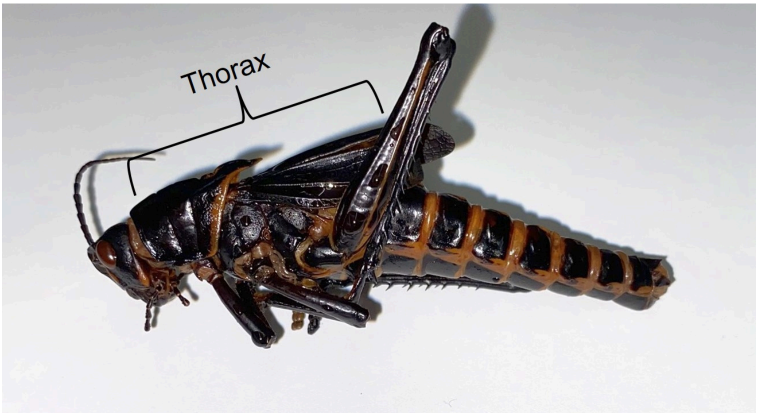
These mouthparts can all be modified into different shapes, textures, and sizes to accommodate different diets – sometimes they are radically altered! For example, in butterflies, the coiled tube that allows the butterfly to drink nectar is formed solely from the galea of the maxillae. In other insects, these structures have been modified to form a “sponge”, the labellum and associated structures, for feeding on liquids (e.g. carrion flies), or piercing and sucking structures (e.g. mosquitoes).


Labrum
Mandible
Hypopharynx
Maxilla
Labium

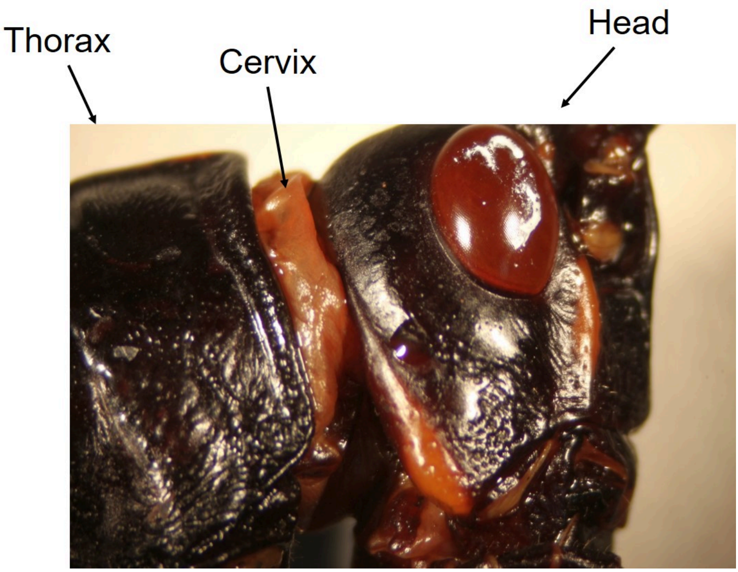
16. Insect Anatomy - The Thorax

Thorax

The thorax runs from the back of the head to the end of the last segment with legs attached.

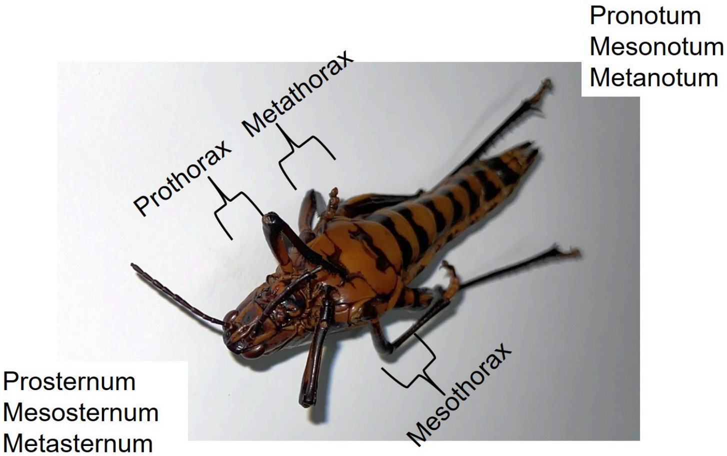


The head and thorax are connected by a membranous area called the cervix.



The thorax itself consists of three segments, which are easiest to see on the lower, or ventral surface. The prothorax is the first segment, nearest the head, and carries the first pair of legs. The mesothorax is the middle segment, and carries the second pair of legs. The metathorax is the third segment, furthest from the head, and carries the third pair of legs.

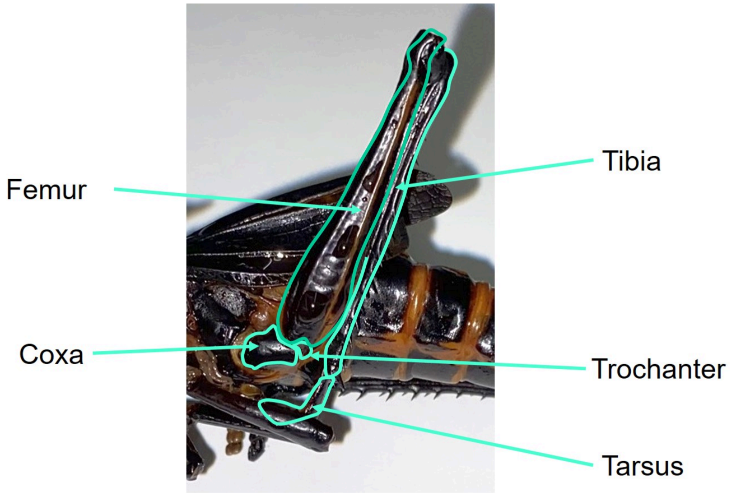
The sclerites on the ventral surface of the thorax are referred to as sterna: prosternum, mesosternum, and metasternum. The sclerites on the dorsal surface of the thorax are referred to as nota: pronotum, mesonotum, and metanotum.



Legs

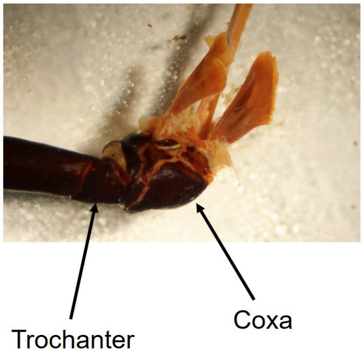
The jointed legs of insects consist of five parts:

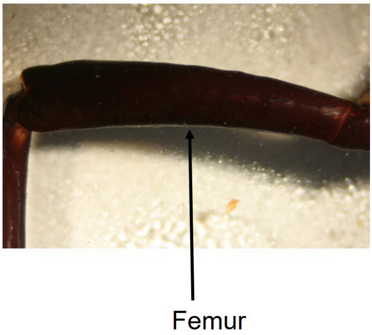
- The coxa joins the leg to the body
- A segment called the trochanter provides greater flexibility in leg positioning
- In the grasshopper the hind femur is very long and muscular, for jumping
- The tibia is also lengthened in the grasshopper
- The final section is a multi-segmented tarsus, which is partly obscured by the middle leg in this photo.



When the leg is removed from the body (this is the middle, or mesothoracic leg of the grasshopper), you can see the large muscles that control and attach it to the body.

The segment nearest the body is the coxa, followed by the trochanter, then the femur…

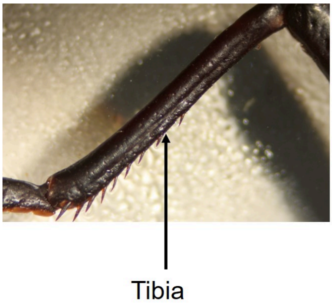


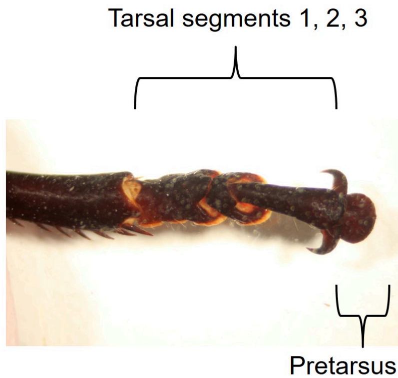


Then the tibia … And, finally, the tarsus.

In the grasshopper, there are three tarsal segments. The tip of last tarsal segment has two claws and a pad, collectively called the pretarsus (not counted as a separate tarsal segment).

Identifying many insects, especially beetles, requires you to count tarsal segments, often on all three pairs of legs.





Wings

The thorax also bears two pairs of wings. The forewings are attached to mesothorax, and the hind wings are attached to the metathorax. The prothorax does not bear any wings. In the grasshopper, the pronotum is enlarged to form a protective shield that extends back over the wing bases.

A number of small sclerites and sutures at the bases allow the wings to articulate with the body with maximum flexibility (more on that in class).

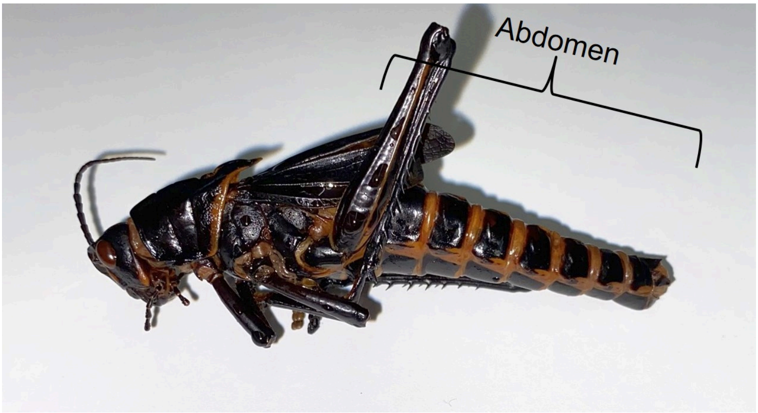
Notice that the front and hind wings differ considerably in texture in the grasshopper. The front wing is tough and leathery serving to protect the hindwing when not flying. The hind wing is membranous, and used for flight (this one was a little mangled, sorry!).

17. Insect Anatomy - The Abdomen

Abdomen

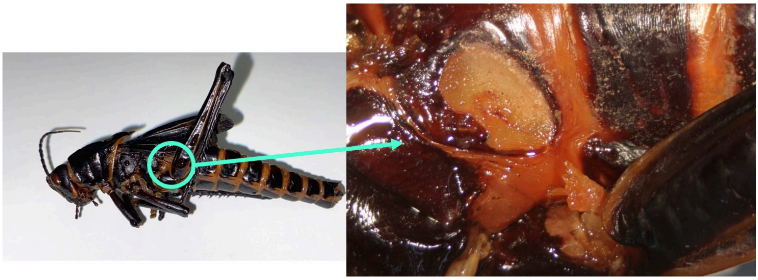
The abdomen includes all of the body segments after the metathorax.

There are no jointed appendages (legs) or wings attached to the abdomen.



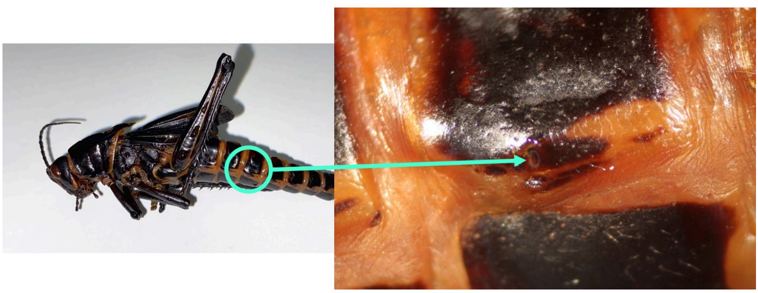
Just above and behind the hind leg of the grasshopper is the tympanum. It consists of a membrane stretched across an opening, which detects vibrations. Grasshoppers use sound in courtship, and territorial displays. The tympanum acts as an "ear" to detect those frequencies.

The tympanum will have different sizes, shapes, and locations in different insects.

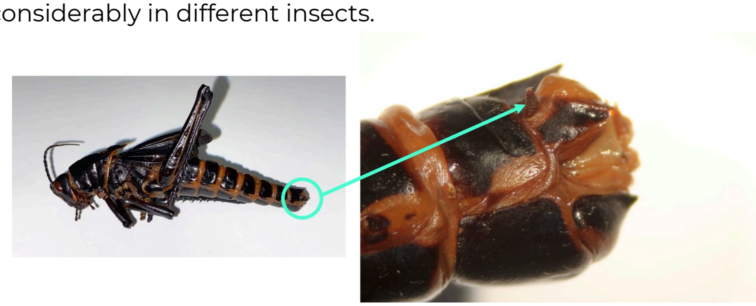


Along the sides of the abdomen, just above the sutures between the tergites and the sternites, you will see one tiny hole per segment. These are the spiracles, or openings of the respiratory system.

You may also be able to see some spiracles on the thorax of some insects.



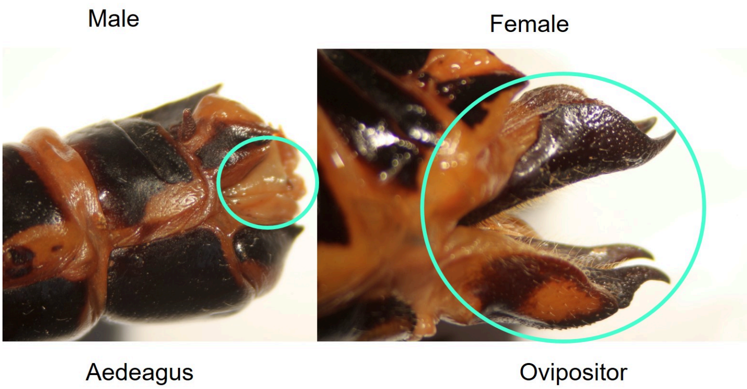
At the tip of the abdomen, there are two small “flaps”, called cerci. The function, shape, and size of the cerci vary considerably in different insects.



Here are photos of the genitalia of both sexes of grasshoppers, on the last abdominal segment. Which sex do you think is which? [The male grasshopper is on the left, and the female is on the right.]

The aedeagus (mostly internal) is used to transfer sperm to the female à the ovipositor, literally the "egg positioner", is used to bury the eggs in hard-packed soil (in grasshoppers).

Both male and female genitalia can look quite different in various insects. They are often important for identifying insects to species.

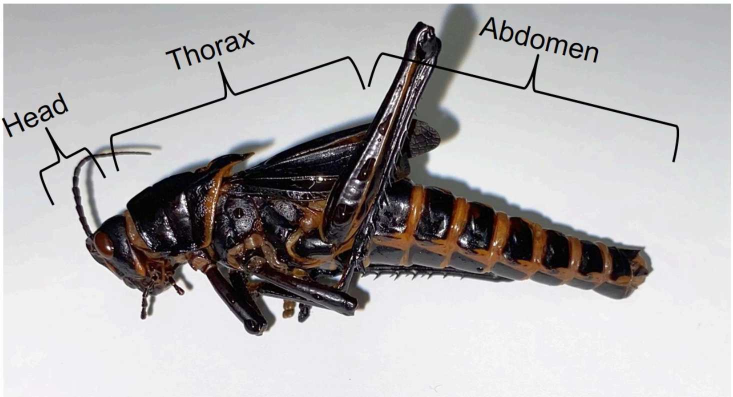


18. Internal Anatomy - Introduction

Internal Anatomy – Introduction

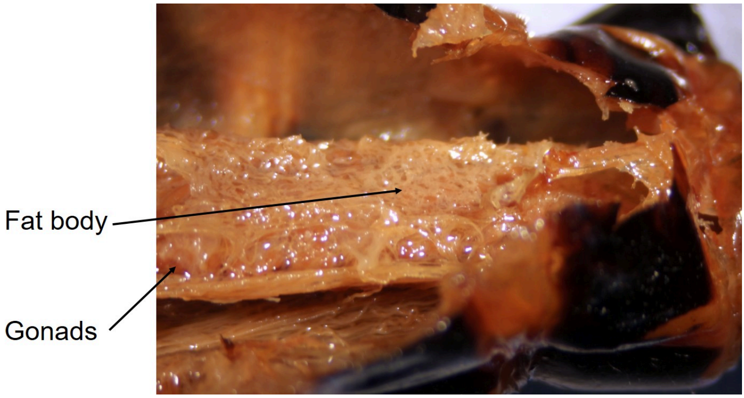
First, remember what the outside of the grasshopper looks like.

In the dorsal body wall, we will find most of the circulatory system; the ventral wall is where the nervous system is most visible; and laterally, at the join between tergites and sternites, is where the spiracles and respiratory system can be seen.



To examine the internal anatomy, the initial incision is made laterally, about halfway between the dorsal midline and the spiracles.

When the grasshopper is first opened, the most obvious structures are usually the gonads (which take up a large proportion of the abdominal cavity in both sexes) and the fat body. In this next photo, the fat body resembles a network or mesh overlying the internal organs. Its function is similar to that of our liver.

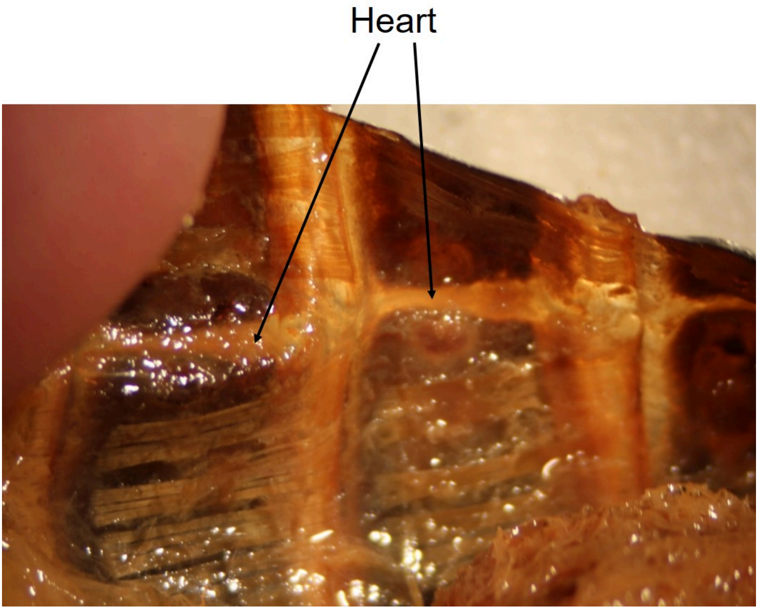

Fat body
Gonads

19. Internal Anatomy - Circulatory System

Internal Anatomy – Circulatory System

The main organ of the circulatory system, the heart, appears as a clear tube running the length of the dorsal midline (our circulatory system is primarily ventral). There is a heart chamber associated with each body segment, and muscles that expand each chamber.

Insects have an open circulatory system. The "blood", called hemolymph, is not always contained within vessels. In most cases, insect hemolymph is not associated with the respiratory system, and does not transport respiratory gases.



Connected together into a long tube, the chambers contract in sequence from the tip of the abdomen towards the head.

These contractions force hemolymph towards the brain, where it spills out into the body cavity, bathing the tissues directly. The hemolymph is then drawn back into the heart chambers through tiny openings called ostia.

See https://www.youtube.com/watch?v=LLPmKydCudY (R. Gibson) for a video of a lining insect's heart in action. The caterpillar in this video is resting, and likely a bit cold, so the heart pauses on occasion (the video also skips a little).

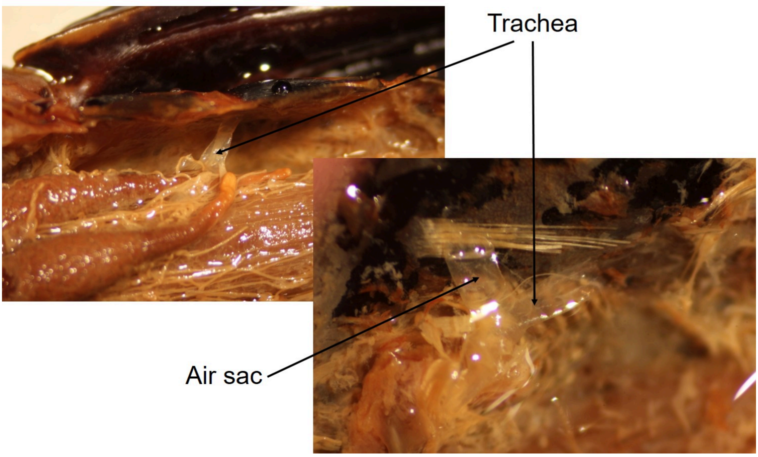
20. Internal Anatomy - Respiratory System

Internal Anatomy – Respiratory System

As it is also a system of clear tubes, the respiratory system can also be difficult to see in a preserved grasshopper.

One of the main tracheae is still connected to the spiracle in the left-hand photo.

Trachea and an associated air sac are visible in the right-hand photo. Air sacs can be used to store air, and to help expand the body when needed.



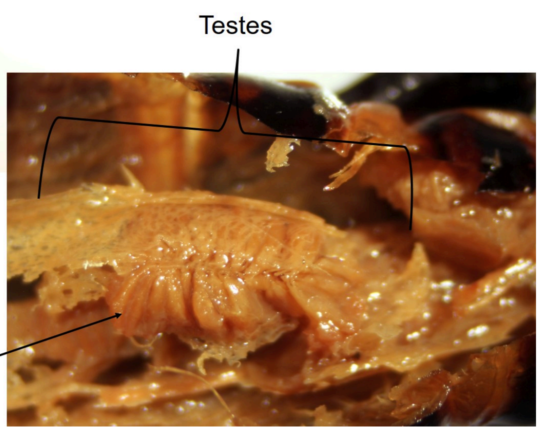
21. Internal Anatomy - Reproductive Systems

Internal Anatomy – Reproductive Systems

A reminder of what the male's external genitalia look like.

Inside you can see the fused testes, with plenty of fat body covering them; the individual segments are called seminiferous tubules. These are the locations for meiosis to produce sperm cells.

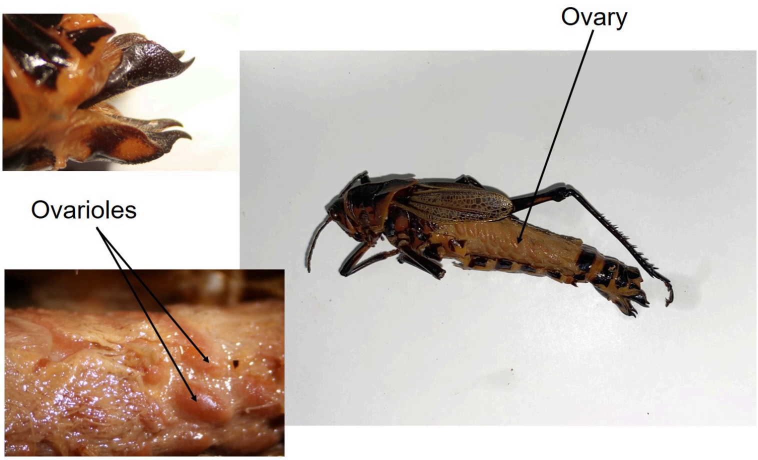
Various accessory glands are also associated with the male reproductive system. These support and protect sperm, and package sperm into a spermatophore in many insects.



A reminder of what the female's external genitalia look like. Note the stout ovipositor.

Following the initial incision on a mature female grasshopper, almost the only organ visible is the fused ovaries, again with plenty of fat body associated. The small sections are ovarioles, where meiosis occurs, with individual ova developing within the ovary.

Again, accessory glands are associated that protect and nourish eggs, and secrete coverings.

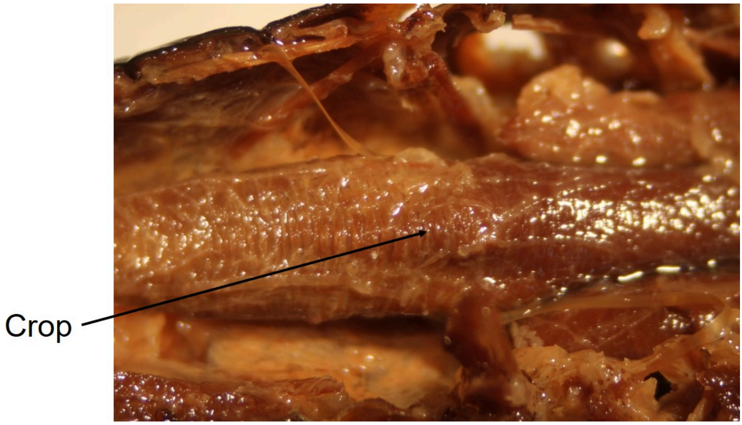


22. Internal Anatomy - Digestive System

Internal Anatomy – Digestive System

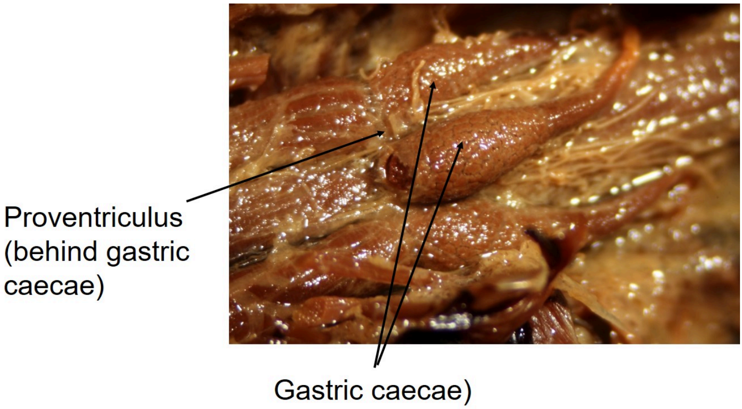
Moving on to the digestive system…

The foregut consists of a short esophagus behind the mouth, followed by large crop (shown here) for storage of ingested food.

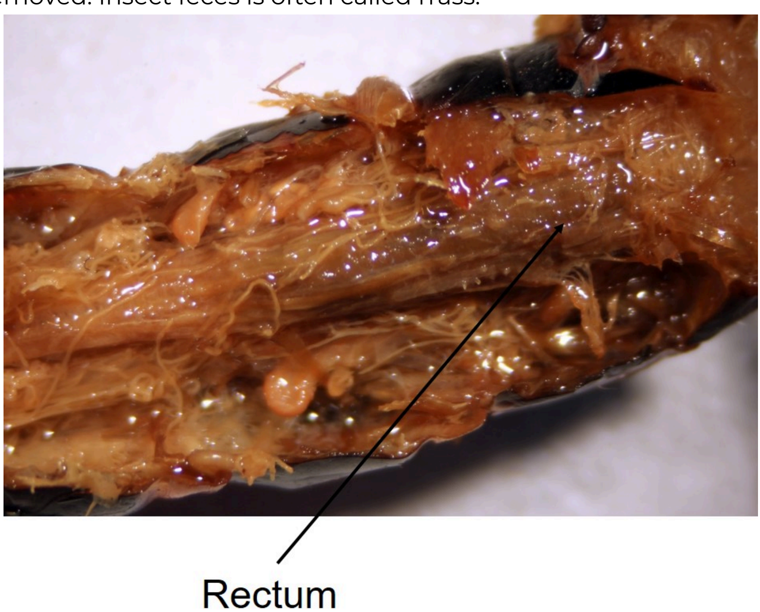


Leaving the crop, the food is passed to the muscular proventriculus. In the grasshopper, mechanical digestion continues here (the proventriculus may contain sclerotized "teeth").

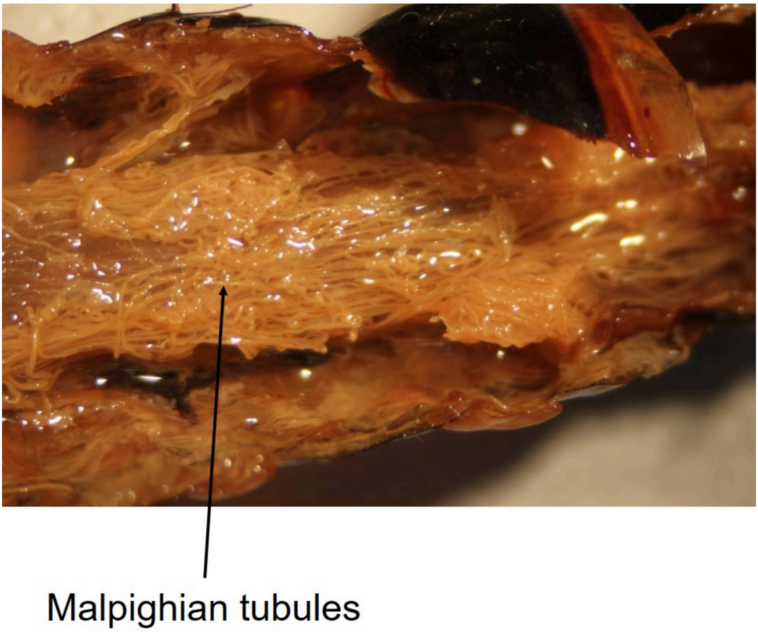
From the foregut, food passes to the midgut. At the junction of the foregut and midgut are several blind pouches called gastric caecae. These increase the surface area for secretion of enzymes, digestion, and absorption.



Finally, the mostly-digested food passes to the hindgut, primarily composed of a thick-walled rectum. The rectum reclaims almost all water from the feces before eliminating it. Most insects produce dry waste products, with almost all water removed. Insect feces is often called frass.



Draining into the hindgut, just posterior to the midgut, are the Malpighian tubules, which are important in osmoregulation and excretion. They are named after Marcello Malpighi, a 17th century anatomist.



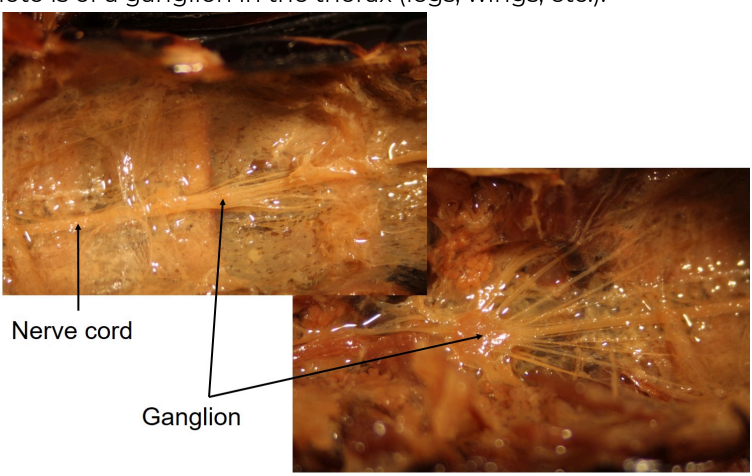
23. Internal Anatomy - Nervous System

Internal Anatomy – Nervous System

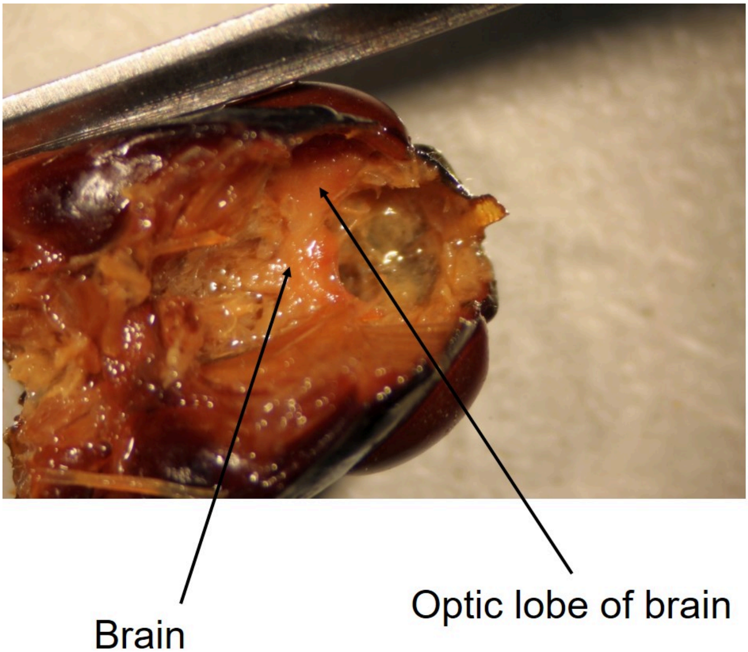
The nerve cord in insects is ventral (ours is dorsal).

There is a ganglion, a concentration of nervous tissue, associated with each segment. Each segment is, therefore, somewhat autonomous, but all segments are coordinated by the brain.

These photos show nerves extending from each ganglion, communicating with various parts of the body. The right-hand photo is of a ganglion in the thorax (legs, wings, etc.).



The nerve cord extends forward to just below the esophagus. Two branches wrap around the esophagus and other internal structures, then rejoin to form the brain. With the back of the head removed, the main structures visible are optic lobes, associated with the compound eyes.


Optic lobe of brain
Brain

PART IV

LAB 2A: IDENTIFYING INSECT ORDERS

24. Introduction

Identification to Order – Introduction

With all this diversity, where do we even start??!

Your text has a number of identification keys at the back. We will be using those to identify insects to order and family. We'll start with the order level. Some orders you will learn to recognize quickly and easily. Those orders are pulled out first, and the remainder will need to be keyed. You may also find this online resource from North Carolina State University (https://genent.cals.ncsu.edu/insect-identification/), or other online resources, helpful.

There is often redundancy built into keys, so if you go wrong somewhere you can still get to an answer. It is always good practice, when you have a result, to go and look at photos, drawings, etc. to see if your identification makes sense!

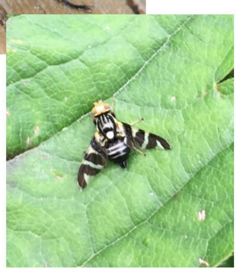
At the order level, you will mostly be looking at various wing characteristics, the type of mouthparts, and sometimes characteristics of the legs.

25. Key Features of Wings

Key Features of Wings

How many pairs? … Here are some insects with only one pair of wings, and the second pair reduced to knobs called halteres. Halteres may or may not be large and obvious. They are easier to see on fresh (or freshly defrosted) specimens. Many insects tend to fold the wings when they die, making it tougher to see if there's a second pair – once the specimen has dried out, DO NOT TOUCH! – it will break!!

Pinzo at English Wikipedia / Public domain



Most insects have two pairs of wings, and sometimes it's obvious.

Obvious ones:

In other cases, it is less obvious. Beetles, for example, generally have two pairs of wings. The front wings are modified into hard covers called elytra. In the top right photo, you can see the hind wings sticking out from underneath the elytra. Beetles fly using their hindwings, then fold them underneath elytra when not flying, to protect them from damage.

Another example occurs in the Hemiptera, or true bugs. The bases of their forewings are leathery, but the tips are membranous (work the same way as elytra in beetles). **Note that the forewings cross over each other, making an “X” on the dorsal surface of the bug.

Hymenoptera also have two pairs of wings, but their hind wings are hooked in to their forewings, and often folded longitudinally, so it can be tough to decide if your insect has one or two pairs of wings.

If in doubt, look at pictures, and please feel free to ask! This is not a stupid question!

Hemelytra

Are the forewings hardened or leathery? … or “dissimilar to hind wings” in some keys.

You saw an example of this on the grasshopper in the anatomy lab. Grasshoppers have leathery forewings. Beetles have elytra (hardened forewings). True bugs have hemelytra (partially hardened/leathery forewings). All of these would count as “hardened or leathery forewings”, and “dissimilar to hind wings”.






Are the front and hind wings similar in size and or shape?

On the left are the wings of a termite and damselfly. Note that the front and hindwings look quite similar in size and shape. On the right, at the top, is a mayfly (front wing larger than hind wing). On the right, at the bottom, is a stonefly (hind wing larger than front wing, and a different shape).

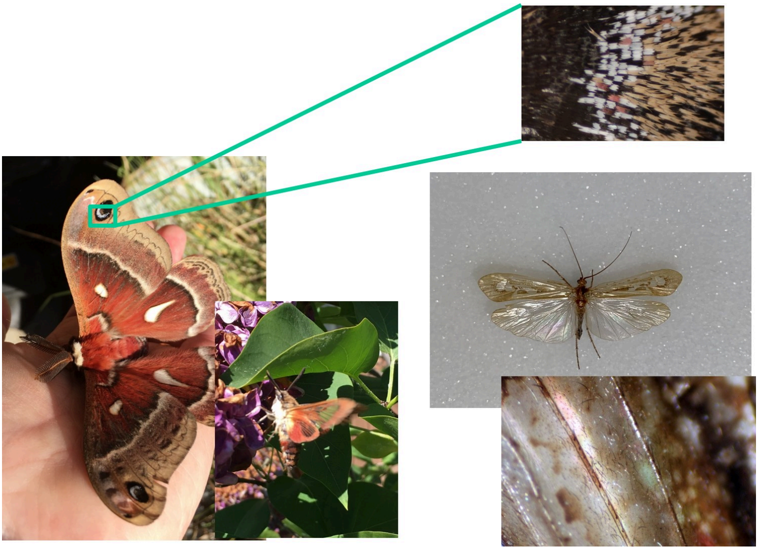



Are the wings covered in scales? or hairs?

Moths and butterflies have wings covered in tiny, flat scales that give them colour patterns

Watch out for a few (e.g. the hummingbird clearwing moth feeding on a lilac) with clear patches on the wings. If you look closely, you will still see has scales around the edges!

Caddisflies (bottom right) look similar to moths and butterflies. Their front wings are covered in hairs, not scales (moths can also be hairy, but always have scales somewhere as well).



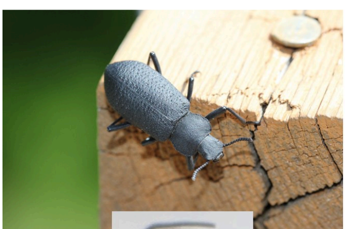
26. Key Features of Mouthparts

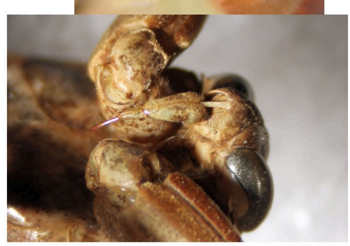
Key Features of Mouthparts

Are the mouthparts chewing (mandibulate), or modified for piercing, sucking, or lapping (haustellate)?

You saw an example of chewing mouthparts (left) in the grasshopper. Multiple parts were visible, including palps.

Some insects have mouthparts modified into a tube (right) for sucking fluids (haustellate mouthparts), e.g. the butterfly mentioned in the anatomy lab. Another example is the true bugs, which have piercing-sucking mouthparts. The flies, or Diptera, have all sorts of modifications, but never have chewing mouthparts.



27. Key Features of Legs

Key Features of Legs

Finally, you may encounter some questions about leg modifications.

For example, mantids have raptorial front legs for grabbing prey; giant water bugs also have grasping front legs.

Grasshoppers and their relatives, of course, have hind legs modified for jumping.



28. Practice!

That should give you a starting point.

Use the dichotomous keys available to try your hand at identifying the insects provided, to order only for now.

When you are comfortable using the key, and have a feel for the orders of insects, you should start thawing some of your specimens and identifying them to order. Knowing the order will help you determine where to put the pin, so you can get your specimens safely mounted.

As always, please ask lots of questions!

To what order does each of these insects belong?





PART V

LAB 3: ENTOGNATHA, APTERYGOTA, AND PALEOPTERA

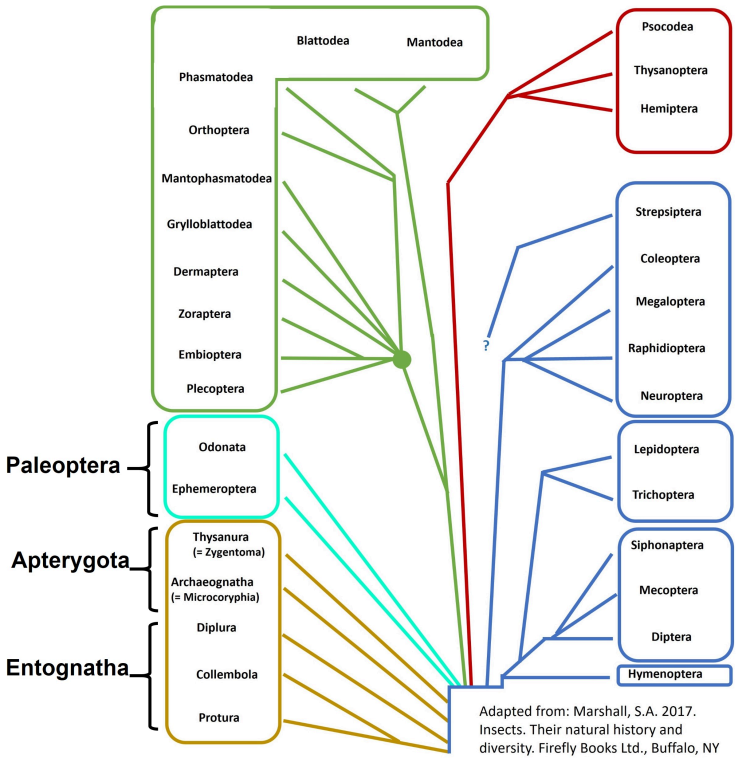
29. Introduction

Introduction

In this week's lab, we will be covering three main groups, with several families in each. In some cases, you will be responsible for being able to identify the order, and in others the family of an insect you are shown. The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can review your understanding.

Early on in your text, you will find this figure. I will use it at the beginning of each of these labs, to show you the groups we will be covering, and their relationships.

This week, we will cover the Entognatha, the Apterygota, and the Paleoptera; there are several taxa in each, as you see.


Blattodea
Mantodea
Phasmatodea
Orthoptera
Mantophasmatodea
Grylloblattodea
Dermaptera
Zoraptera
Embioptera
Plecoptera
Paleoptera
Odonata
Ephemeroptera
Apterygota
Thysanura
(= Zygentoma)
Archaeognatha
(= Microcoryphia)
Entognatha
Diplura
Collembola
Protura
Psocodea
Thysanoptera
Hemiptera
Strepsiptera
Coleoptera
Megaloptera
Raphidioptera
Neuroptera
?
Lepidoptera
Trichoptera
Siphonaptera
Mecoptera
Diptera
Hymenoptera
Adapted from: Marshall, S.A. 2017.
Insects. Their natural history and
diversity. Firefly Books Ltd., Buffalo, NY

30. Entognatha

The Entognatha

We'll start with the Entognatha, a polyphyletic group. These animals are no longer considered part of the class Insecta, but are still included in the subphylum Hexapoda.

There are three orders within the Enognatha: Protura, Diplura, and Colllembola (also called springtails). All have mouthparts carried inside the head, in a pouch-like structure.

Protura

The class Protura ("Prot" = "first", "ura" = "tail"), or coneheads, include approximately 500 species worldwide, with 20 species in three families in North America. The order was first discovered in 1907, and can easily be separated from leaf litter samples using Berlese funnels or Tullgren funnels (let me know if you would like to try collecting Protura). They are quite common, and a survey in California found ~4000/m2. All are less than 2.5 mm. They lack eyes, antennae, cerci and tracheae. Their legs have five segments, with one-segmented tarsi. The forelegs are enlarged, and used as antennae. The mouthparts are styliform, and used for sucking. There may be limb-like appendages on the first 3 abdominal segments, with terminal vesicles on the first pair.

One final point of interest about the Protura: they show anamorphic development. If you don't remember this term from Invertebrate Zoology, it means that the animal adds a body segment at each moult.

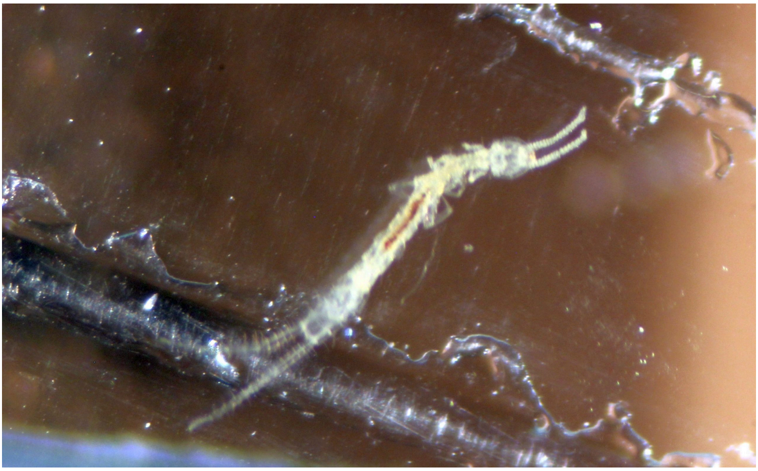
In BC, we have 2 of 3 families present in North America. There is one slide of a local species available for identification to order.

Diplura

The second class we cover in the Entognatha is the Diplura ("diplos" = "double", "ura" = "tail"). There are about 800 species of Diplura worldwide, with 65 species in four families known from North America. They can be locally common, but are small and prefer damp areas such as leaf litter. They lack eyes, but have chewing mouthparts, and well-developed antennae and cerci. The cerci are autotomizing: again, if you don't remember that term from Invertebrate Zoology, it means that the cerci can be lost voluntarily to help the animal avoid predators.

Diplura have an interesting courtship. Once a male has found a female, he will leave a spermatophore, or a packet of sperm, on the ground. She will then fertilize herself using the sperm in the spermatophore.

There is one slide of a local species available for identification to order.



Collembola

Among the Entognatha, you are most likely to be familiar with, or at least to have seen, members of the class Collembola ("coll" = "glue", "embolon" = "peg"), the springtails. There are well over 6000 species of springtails worldwide, with at least 675 species in North America and 541 on the Canadian checklist. They can be found from the Arctic to Antarctica, and often occur at high densities.

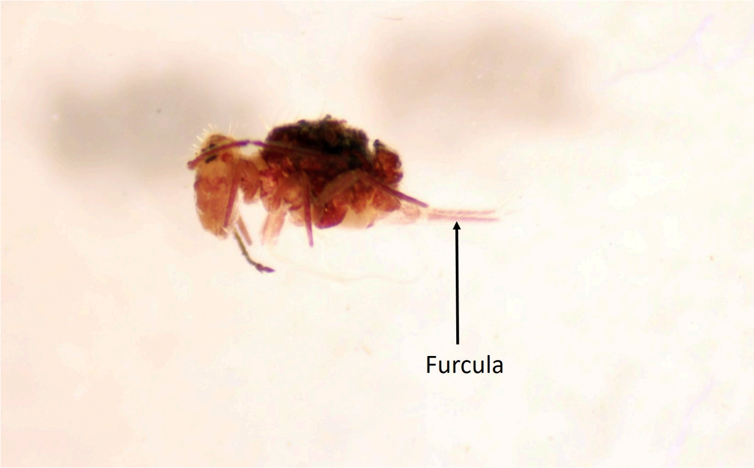
Springtails have chewing mouthparts, antennae with four to five segments, and a one-segmented tarsus. The tarsus may also be fused with the tibia, forming a tibiotarsus. They also have a small eye patch, similar to the stemmata you will encounter later in the course in some larval insects. They do not have cerci, and some lack tracheae. There are six abdominal segments. Springtails have an eversible vesicle, called the collophore, which functions in osmoregulation, water absorption, and (possibly) adhesion to the substrate. The name "springtails" comes from a structure that some Collembola have on their abdomens. There can be a forked structure, hinged to the tip of the abdomen, called a furcula. The furcula is tucked into a small structure further forward on the ventral surface of the abdomen, called the tenaculum or reticulum. When the animal is disturbed, the furcula can be released with considerable force, propelling the springtail off the substrate. Not all springtails have a furcula.

Fertilization occurs via a spermatophore deposited on the ground. In this order, though, the antennae in the males of some species are prehensile. The male can use them to hold the female and lead her to the spermatophore.

Ecologically, springtails are very important in soil function. Most feed on organic matter, helping with fragmentation and decomposition. A few species can even be considered pests, e.g. in greenhouse and nursery settings. Some are also predaceous, while others are herbivorous. "Snow fleas" are often encountered in the early spring in Prince George, feeding on algae and pollen on the snow surface. They are noticeable because, as with many springtail species, their bodies are covered in opaque scales, causing them to look yellow, purple, or blue against the snow.

Some of our local species are shown below. Note that the class Collembola is divided into two subclasses, the Arthropleona and the Symphypleona (globular springtails). Also, remember that not all springtails have an evident furcula!


Furcula


Furcula

31. Apterygota - Archaeognatha

Apterygota

The first two orders we will cover from the class Insecta are in the Apterygota. These orders are ancestrally wingless.

Archaeognatha (=Microcoryphia)

The Archaeognatha (“archeo” = “old”, “gnatha” = jaw) are characterized by mandibles that are monocondylic; that is, they have a single point of articulation with the head. The order is sometimes referred to as Microcoryphia (“micro” = “small”, “coryphia” = “head”). They are commonly called jumping bristletails. There are ~350 species worldwide, with 20 species in two families represented in North America.

Jumping bristletails have bodies covered with flat scales, and are no more than 15 mm long. They have both compound eyes and ocelli, as well as long antennae. The compound eyes are large and meet on top of the head. Both the mesothoracic and metathoracic coxae have styli, and tarsi are two- to three-segmented. Two cerci are present, relatively short compared to the cerci of the next order (Zygentoma/Thysanura), and there is also a central caudal filament.

Archaeognatha are fairly common in wooded areas around Prince George and can sometimes be found in urban habitats. They are relatively soft-bodied so, like most of these ancestral orders, must be preserved in ethanol.

32. Apterygota - Zygentoma

Zygentoma (=Thysanura)

The order Zygentoma ("zyg" = "bridge", "entom" = "insect") or Thysanura ("thysan" = "fringe", "ura" = "tail"), the silverfish, superficially resemble the Archaeognatha. They have flatter bodies, smaller eyes, and dicondylic mandibles with two points of articulation with the head. There are ~370 species worldwide, with 18 species in three families in North America.

Silverfish are more dorsoventrally flattened than the Archaeognatha, and the tarsi are three- to five-segmented. Ocelli are present, but the compound eyes are much smaller than those of the Archaeognatha and are sometimes absent. The two cerci are far longer in the silverfish than in the jumping bristletails, and the caudal filament is long as well.

We rarely collect these animals, although they occasionally show up in e.g. ground floor suites. They are soft-bodied, so must be preserved in ethanol. Our specimens are becoming rather battered, but note the long (broken!) cerci, caudal filament, and antennae as well as the small compound eyes.

33. Paleoptera - Ephemeroptera

Paleoptera

All of the other insects we cover can be grouped in the Pterygota, or winged insects. The last group for this week's lab is the Paleoptera, or "ancient-winged" insects. These animals are unable to fold their wings at rest. We will look at two orders: Ephemeroptera (mayflies), and Odonata (dragonflies and damselflies).

Ephemeroptera

The Ephemeroptera ("ephemeros" = "short-lived", "pteros" = "wing"), or mayflies, can be very difficult to key to family as adults and impossible to identify as small nymphs. There are some good keys to mature nymphs. I encourage you to attempt identifying some of the specimens shown in the lab (and, of course, any specimens that you submit with your insect collection assignment!) to the family level, but don't spend a lot of time on them. If you can identify the order, that is sufficient for the lab exam. In particular, note the large, triangular forewings and smaller hindwings. The hindwings may be completely absent.

Mayflies undergo hemimetabolous development (we will cover that term in the class). In this form of development, the nymph, or immature stage, is entirely aquatic. They are also called "naiads" (= "water spirits"). Nymphs of some species can live for several years. They have flat, feather-like gills along the abdomen. Species from lotic habitats have various adaptations for clinging to rocks and other substrates, and are often dorsoventrally flattened. Once the nymphs have completed development, they swim to the surface and moult to the adult stage. This is one of few insects to moult as an adult (fly fishers:

dun moults to spinner). They tend to have very short adult lives, so tend to emerge synchronously in very large numbers to facilitate finding a mate.

The photos of adult Ephemeroptera were kindly provided by Danie Erasmus (an avid fly fisher). Both adults and nymphs must be preserved in ethanol.

34. Paleoptera: Odonata

Odonata

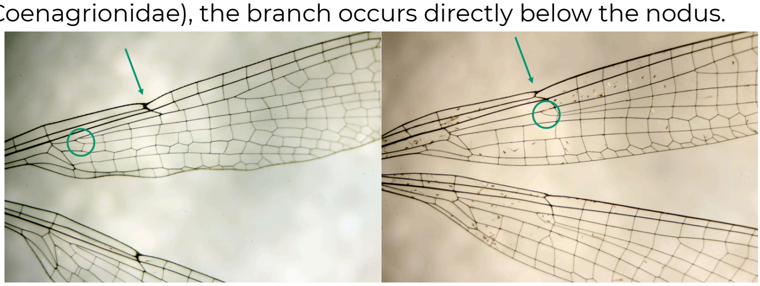
The Odonata ("odon" = "tooth") includes about 5000-6000 species, with 87 species in 10 families known to occur in BC. The order is, in most literature, divided into two suborders, the Anisoptera (dragonflies; "aniso" = "unequal") and the Zygoptera (damselflies; "zygo" = "joined together"). These names come from the relative size and shape of the front and hind wings. The Anisoptera have larger hindwings and smaller forewings, while the two pairs of wings are a similar shape and size in the Zygoptera. The two suborders also differ in body shape and size, in their ability to hold the wings parallel to the body at rest, and in various characteristics of the immature stages.

The entire order is carnivorous, both as immatures and adults. Adults catch prey in flight, and are adept, agile flyers. They also have large eyes, making them difficult to catch with an insect net! The immature stages are aquatic, so adults are often found near water bodies. They are strong fliers, though, and can disperse long distances.

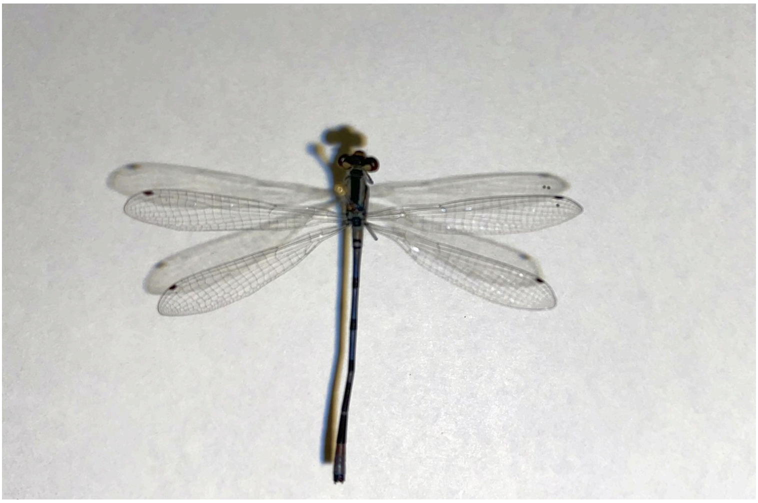
Development in the Odonata is hemimetabolous. Mating occurs in flight, and the male may clasp the female for some time to prevent multiple matings. The spermatophore is placed in a secondary reproductive organ either before (Anisoptera) or after (Zygoptera) a female is found. Nymphs, or naiads, are aquatic, lie-in-wait predators. They have an extensible labium that is specialized for catching prey. Nymphs must be preserved in ethanol, but are relatively easy to identify to family using characteristics of the labium, among other features. Zygoptera nymphs tend to be slenderer than Anisoptera nymphs. Zygoptera also have three leaf-like, external gills at the tip of the abdomen. Anisoptera are stouter, and have internal gills held inside the rectum. When disturbed they take water into the rectum and expel it forcefully, to “jet” away from a potential predator.

To identify adult Odonata, you will have to use features of the wings and wing veins. Your key will refer to “triangles” in the wing veins of Anisoptera. These patterns are outlined below, with the left figure (Aeshnidae) showing triangles that are equal in the forewing and hindwing, and the right figure (Libellulidae) showing triangles that are not equal.

In the Zygoptera, you will need to determine where a certain wing vein in the forewing branches relative to the nodus. The nodus is the dark spot along the wing margin indicated by the arrows in the following photos. In the left figure (Lestidae), the branch occurs before, or basal to, the nodus. In the right figure (Coenagrionidae), the branch occurs directly below the nodus.



Following are some photos of Anisoptera (left) and Zygoptera (right), both adults (top) and nymphs (bottom). Note the formidable labium on each nymph!



PART VI

LAB 4: ORTHOPTEROID ORDERS

35. Introduction

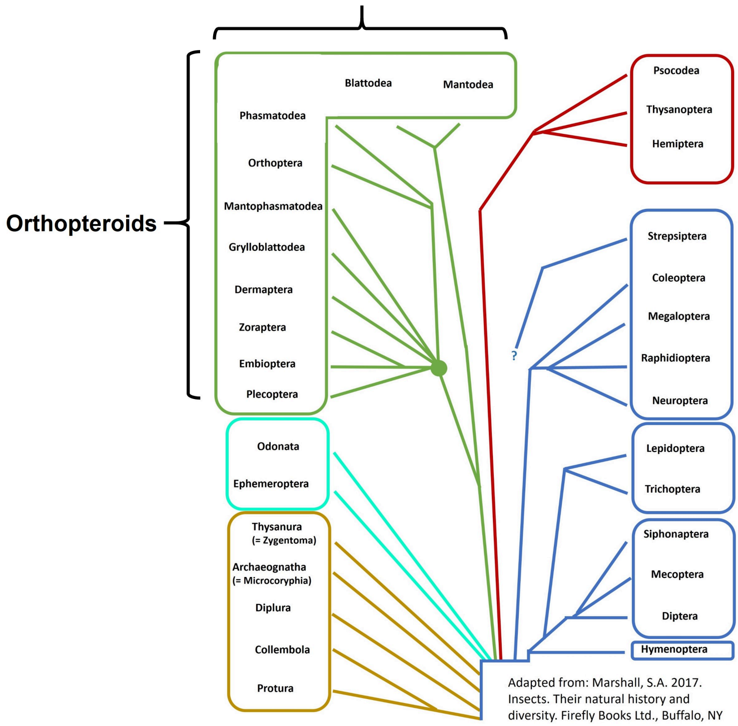
Introduction

This week's lab will cover the orthopteroid orders, with an emphasis on those taxa found in northern BC. Your goal is to learn how to identify various common insects to order and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

The orthopteroids include several orders of insects:

- Plecoptera, the stoneflies;
- Dermaptera, the earwigs;
- Orthoptera, the grasshoppers, crickets, and katydids;
- Blattodea, the cockroaches and termites;
- Phasmatodea, the stick and leaf insects;
- and Mantodea, the mantises

Several other, mostly tropical, orders are also included for interest, but you will not be expected to identify them. Only the Orthoptera will be identified to family in the lab, and only a few families will be covered. If your collection includes orders or families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know!


Orthopteroids
Blattodea
Mantodea
Phasmatodea
Orthoptera
Mantophasmatodea
Grylloblattodea
Dermaptera
Zoraptera
Embioptera
Plecoptera
Odonata
Ephemeroptera
Thysanura
(= Zygentoma)
Archaeognatha
(= Microcoryphia)
Diplura
Collembola
Protura
Psocodea
Thysanoptera
Hemiptera
Strepsiptera
?
Coleoptera
Megaloptera
Raphidioptera
Neuroptera
Lepidoptera
Trichoptera
Siphonaptera
Mecoptera
Diptera
Hymenoptera
Adapted from: Marshall, S.A. 2017.
Insects. Their natural history and
diversity. Firefly Books Ltd., Buffalo, NY

36. Plecoptera

Plecoptera

The first orthopteroid order we cover is the Plecoptera ("plektos" = "folded"), or stoneflies. There are about 2500 species worldwide, and about 500 in North America. A few species are quite large, but most are small. Adults are generally poor fliers, with short dispersal distances, and are found near aquatic habitats.

The immature stages are mostly aquatic, and common in cold streams and other habitats. These nymphs/naiads are mostly herbivorous, with a few predatory species; some seem to switch from herbivory to carnivory. Some New Zealand species have terrestrial nymphs, and one species in Lake Tahoe is entirely aquatic, even as an adult. Nymphs are similar to Ephemeroptera nymphs, but have two tarsal claws (not one), cerci but no caudal filament (so, two "tails" not three), and their gills are hair-like tufts that are never found along the abdomen.

Both nymphs and adults are often preserved in ethanol (more delicate species tend to shrivel when air-dried), but robust adults can be pinned. There are several families represented in northern BC.

37. Dermaptera

Dermaptera

The Dermaptera ("derma" = "skin"), or earwigs, include about 2000 species worldwide. One species, *Forficula auricularia* (Forficulidae), is found locally. This species was introduced to North America in the early 20th century. There is also a larger, darker species found along the southern coast of BC, usually near beaches and seaweed.

Earwigs are nocturnal omnivores. Several species, including the introduced one found in Prince George, are considered nuisance pests as they can move into houses; they can also be smelly. They can damage agricultural crops if numbers are high. They are paurometabolous, with terrestrial nymphs. Adults exhibit a considerable degree of parental care, cleaning, rotating, and spreading out their eggs.

Adult earwigs have relatively dorsoventrally flattened bodies, short wings, and often very pronounced cerci. They will, when threatened, lift the tip of the abdomen and look threatening; however, they are harmless.

38. Orthoptera - Caelifera

Orthoptera

The order Orthoptera includes about 20,000 species of grasshoppers, crickets and katydids. Many of these were, and are still being, documented from the tropics. All of the insects in this order are paurometabolous, with terrestrial nymphs that closely resemble adults. The Orthoptera have enlarged hind femora. Most species are herbivorous, and many communicate using sound, produced by stridulation. There are two suborders, the Caelifera and the Ensifera.

Caelifera

The Caelifera, or short-horned grasshoppers (referring to their relatively short antennae), includes the grasshoppers and locusts (Acrididae), pygmy grasshoppers (Tetrigidae), and the mole crickets (Gryllotalpidae). Insects in this suborder are mostly quite active, able to jump and fly to escape predation, and found primarily on open terrain. There are about 27 species in BC.

Acrididae

Many of the Acrididae are extremely important pests, e.g. “plagues” of locusts. They are also ecologically important, providing an essential food source for many nesting and fledging birds, including burrowing owls. You have already seen the distinctive anatomy of one species of Acrididae, the lubber grasshopper. While your textbook key differentiates between subfamilies, you do not need to identify specimens in the lab (or your collections) to this level.

Tetrigidae

The Tetrigidae are small grasshopper-like insects. They are characterized by a long, pointed pronotum that extends backwards to almost cover the wings. There is at least one species commonly caught in Prince George.

Gryllotalpidae

The mole crickets look quite different from a typical grasshopper. The Gryllotalpidae are burrowing insects with highly modified front legs for digging. They are occasionally considered to be pests, for example on golf courses and in turf farms.

39. Orthoptera - Ensifera

Ensifera

The Ensifera, or long-horned grasshoppers (referring to their relatively long antennae), includes three families, the Gryllidae, the Tettigoniidae, and the Raphidophoridae, that you will see in this lab. Many insects in this suborder are cryptic. New species are being described all the time, especially from the tropics. There are some important economic pest insects in this group, but they can also be cultivated as food for humans and domestic animals including pets. There are about 40 species in BC.

Gryllidae

The family Gryllidae, or crickets, are common in open fields and other environments. They are omnivorous, and are sometimes found in homes seeking warmth and shelter. Several species are very easy to breed in captivity. These are used in the pet industry, and are now being mass-reared (even in North America) to produce protein-rich food/supplements for humans as well. Again, although your text includes key steps to determine subfamilies, you do not need to identify specimens in the lab (or your collections) to this level.

Tettigoniidae

The family Tettigoniidae, or katydids, also tend to frequent open fields. Many katydids are coloured and elaborately sculpted to resemble the vegetation on which they feed and rest. They can be relatively large, and the females often have large, noticeable ovipositors for placing eggs in the soil or in plant material. The jumping hind legs can also be quite pronounced. Some species have reduced wings as adults.

Raphidophoridae

The Raphidophoridae, or cave crickets, are sometimes collected by students in this class. They occasionally enter buildings, and are usually found in dark, slightly humid, enclosed spaces. They can be quite small, and usually have reduced (or absent) wings as adults.

40. Blattodea

Blattodea

Next, we cover the order Blattodea, which includes both the cockroaches and the termites. There are several families that can be caught in BC. There are about 6500 species worldwide with about 50 species of cockroaches in North America. Four species of termites are represented in BC, from three families (one is an introduced species).

Cockroaches

One translation of Blattodea is “shun the light”, for the typical pest cockroach behavior of running for shelter when lights are turned on. As you are, no doubt, aware, cockroaches can be of economic importance in human dwellings. These pest species are all of tropical or subtropical origin. Most cockroach species are not pests, though, and can be very important to their ecosystems.

Cockroaches are paurometabolous, and all produce egg cases called oothecae. Many are subsocial, showing parental care. They were among the earliest dominant groups of Neoptera, and appear to have been an ancestral group to termites. The wood roaches have very similar gut symbionts to termites. Cockroaches tend to have dorsoventrally flattened bodies, with well-developed wings and a large pronotum, as well as chewing mouthparts.

Termites

The termites were, until recently, grouped in a separate order, the Isoptera ("iso" = "equal"). Molecular similarities, as well as similarities in gut symbionts, have now led to them being grouped with the cockroaches in the Blattodea. There are about 2300 species of termites worldwide, all of which feed on cellulose with the aid of symbiotic protozoa in their guts. This feeding behavior brings many species into serious conflict with humans, and termites can be important structural pests in tropical and subtropical areas.

Like the cockroaches, termites are all paurometabolous. They do not carry oothecae, though. Many termites are eusocial, with a well-developed caste system. Male and female reproductives are winged, and courtship flights can be gruelling. The male stays with the female. Their offspring fulfill the roles of soldiers, workers, or other castes in the colony. In one ancestral genus, *Mastotermes*, the nymphs serve as workers. These colonies also have pseudergates, or "false workers". Pseudergates are capable of undergoing a "reverse moult", to fill any shortages in the castes present in the colony.

Some tropical termite species construct large and elaborate mound nests. The tunnels inside these mounds provide built-in ventilation and cooling systems, a fertile line of inquiry for architectural research.

In BC, our most commonly-found termite species is the Pacific dampwood termite, *Zootermopsis angusticollis*. As the common name suggests, this species nests in wood that is damp and, therefore, usually decaying. They are important agents in the decomposition of large trees and coarse woody debris on the coast. Winged reproductive are dorsoventrally flattened and have front and hind wings that are almost identical in shape and size. The soldiers have large jaws for defense, and the workers are small and white.

41. Phasmatodea

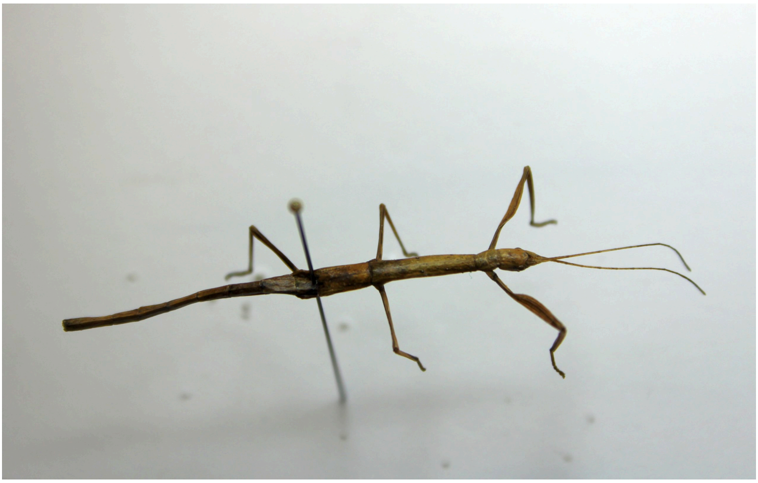
> Several other orders are included in the orthopteroid group. None are found locally, although we have a couple of representatives in the collection (former pets).

Phasmatodea

The order Phasmatodea (“phasm” = “phantom”) is commonly known as the walkingsticks, stick insects, and leaf insects. There are about 2500 species in this order, most of which are tropical herbivores. They tend to be quite cryptic, mimicking vegetation and enhancing that mimicry through behaviours like posturing. An interesting group with a fascinating range of behaviours, two in particular are worth you investigating further: *Timema* species are native to the western United States and the genus is considered a basal group within the order; and the Lord Howe Island stick insect, or tree lobster, is a remarkable conservation success story, including a captive breeding program.

Reproduction in this order ranges from sexual to completely parthenogenic, and two species are estimated to have been parthenogenic for more than a million years. Development is paurometabolous, like all the orders we cover in this lab. Eggs are usually dropped on the ground. They often have a capitulum, a protein-rich structure that attracts ants, analogous to the elaiosomes on many plant seeds.

There is a single native species in Canada, the northern walkingstick (*Diapheromera femorata*), found occasionally in southern Ontario, Quebec, and Manitoba. Other species are usually encountered as part of the pet trade. These should be managed carefully as some species have the potential to establish and even become invasive.



42. Mantodea

Mantodea

The order Mantodea (the Greek root is interpreted as meaning either a soothsayer or a type of grasshopper) are the praying mantises, or simply mantids. Globally, there are about 2000 species, with one North American family plus two introduced species.

Mantids have an elongate prothorax that allows the head to turn dramatically. Mantids also have high visual acuity. They are lie-in-wait predators, with raptorial forelegs. They hunt using vision, and the striking speed can be 0.03-0.05 seconds. They rely on (sometimes quite elaborate) camouflage and behaviours to conceal them from their prey.

Mantids are closely related to cockroaches. They reproduce sexually and are paurometabolous. In a few species, but not all, the male requires decapitation in order to release sperm. His body can then be consumed by the female to provide extra nourishment for her developing eggs. Eggs are laid into an ootheca, which is essentially a layer of froth produced by the accessory gland that hardens on exposure to air.

The ground mantid, *Litaneutria minor*, is native to sagebrush areas in the extreme south of the Okanagan Valley. This species is red-listed and should not be collected. Others that you may encounter are products of the pet trade, or otherwise imported.

43. Other Orthopteroid Orders

> We have no specimens of the last four orders. You should be aware of their existence, but will not be required to identify them in the lab.

Embioptera

The Embioptera ("embio" = "lively", referring to the speed of movement of the wings), or webspinners, are found in tropical and subtropical regions. They can fly both forwards and backwards. Adults have enlarged front tarsi, from which they can produce silk.

Zoraptera

The Zoraptera ("zora" = "pure", "aptera" = "wingless") do not have a common name. When first discovered, this was thought to be an order with only wingless insects. Winged, or alate, forms were found later. The order contains a single tropical and subtropical family, with one genus and 34 species. All are fairly small, ~3mm, and gregarious. Their relationships, phylogeny, and ecology are not well-understood.

Grylloblattodea

The Grylloblattodea, or rock crawlers, are found only at high elevations and in cave habitats. They are active only in the cold. As the weather warms seasonally, they will burrow down to the permafrost layer.

Mantophasmatodea

The Mantophasmatodea, are commonly known as the gladiators or heelwalkers. The order is restricted to South

Africa, and was first described in 2002. They are sometimes grouped with the Grylloblattodea as suborders of Notoptera: they are evidently closely related.

PART VII

LAB 5: HEMIPTEROID ORDERS

44. Introduction

Introduction

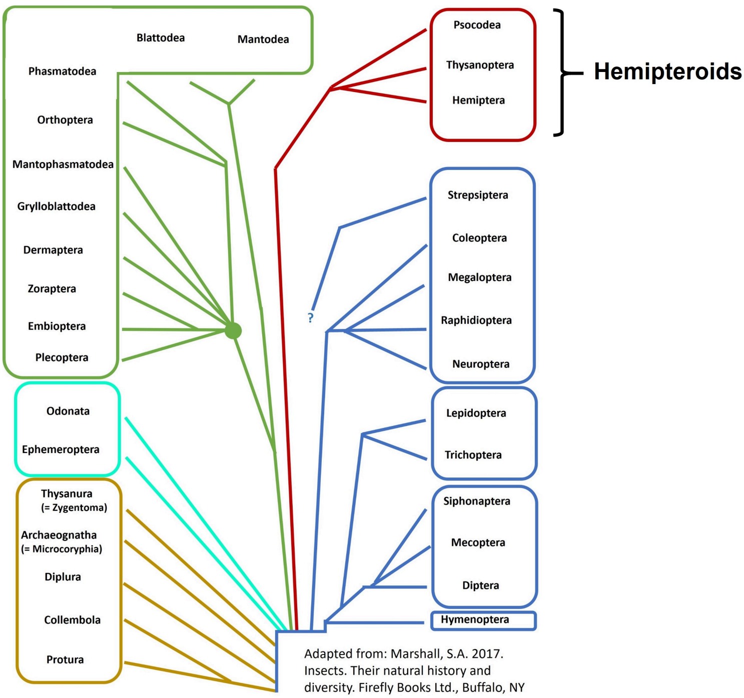
The hemipteroid orders are next, with an emphasis on those taxa found in northern BC. Your goal is to learn how to identify various common insects to order and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

The hemipteroids include three orders of insects:

- Psocodea, including the lice (formerly order Phthiraptera) and the booklice/barklice (formerly order Psocoptera);
- Thysanoptera, the thrips;
- and Hemiptera, the true bugs

If your collection includes orders or families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know!

The level of detail you need to see in order to separate out the number of families in a given order will increase rapidly starting this week! If you are working entirely online, I hope that my minimal photography skills are up to the challenge. If you are having difficulty seeing what the key asks for, or you aren't sure what a photo shows, please ask, or arrange a time to visit the lab and observe the insects in person.



Adapted from: Marshall, S.A. 2017. Insects. Their natural history and diversity. Firefly Books Ltd., Buffalo, NY

45. Psocodea - Lice

Psocodea

The first two hemipteroid taxa we cover are the Phthiraptera, or lice, and the Psocoptera, or booklice and barklice. These two former orders are now usually grouped within a single order, the Psocodea. Older references may still separate them, and/or use the older names.

All members of the Psocodea are small and soft-bodied. They are, therefore, best preserved in ethanol.

“Lice” (formerly Phthiraptera)

The original name for this group of insects, Phthiraptera, can be translated literally as “wingless lice” (“phthir” = “lice”, “aptera” = “wingless”). All members of this group are ectoparasitic on vertebrates. To maintain this lifestyle, their bodies tend to be dorsoventrally flattened, and they are secondarily wingless even as adults. Secondarily wingless means that they evolved from ancestors that were winged as adults. All lice are paurometabolous.

There are about 5,000 species of lice described, which can be divided into two main subgroups. Mallophaga, the chewing lice, live on the feathers or hair of their hosts, feeding on dead skin and other debris. The Anoplura, or sucking lice, also live amongst the hair or feathers, but pierce the skin to feed on blood and other fluids. There is a Mallophaga specimen in the left-hand photo, and an Anoplura specimen on the right.

Humans are host to two species of Anoplura lice in the family Pediculidae. The head louse and the body louse are subspecies of *Pediculus humanus*; the pubic louse is a separate species, *Phthirus pubis*.

46. Psocodea - "Booklice"/Barklice"

“Booklice/Barklice” (formerly Psocoptera)

The second group of insects in this order was formerly known as the order Psocoptera (“psoco” = “small rub” – referring to the feeding abrasions that they make). Their mouthparts are modified for scraping. There are more than 5,500 species, with more still being described.

The booklice and barklice, while closely related to lice that parasitize vertebrates, are not parasitic. Barklice generally feed on fungi, algae, lichens and detritus found in natural environments. Some species are generalist feeders on any organic material. A few of these have become associated with libraries, feeding on the organic paste once used in binding books.

Psocopterans are small, usually ~1-10 mm. As adults, they have two pairs of wings, although some species have no wings at all even as adults. They are all paurometabolous. A distinctive feature of the group is a smoothly bulging clypeus, which gives the head a recognizable shape

This specimen was caught in a pitfall trap at the Aleza Lake Research Forest.

47. Thysanoptera

Thysanoptera

The Thysanoptera ("thysan" = "fringe"), or thrips, are small insects ranging from ~0.5-14 mm, with most about 1 mm in length. Due to their small size, they are best preserved in ethanol or on microscope slides. The common name, thrips, is used as both a singular and a plural noun. In other words, you can see "a thrips", or "many thrips".

Thrips have asymmetrical, sucking mouthparts that they use to feed on plant fluids. Some species are wingless as adults, while others have very narrow, fringed wings. They are paurometabolous, but some have life stages that resemble prepupae and pupae. Some Australian gall-forming thrips have been shown to have haplodiploid sex determination (similar to that found in eusocial bees), and are social. They have even evolved a caste system, including soldiers.

Because thrips pierce plant cuticles to feed on fluids, they can be very important plant pests. In addition to the direct effects on plants (e.g. western flower thrips in greenhouse crops), they are key vectors of a number of plant viruses.

48. Hemiptera - Heteroptera

Hemiptera

Hemiptera is a large, varied order, with more than 55,000 species. Many species are cryptic, feeding on roots or inside galls, meaning that there are probably many more species still to be described. The order name refers to the forewings in one subgroup being hardened or leathery at the base only ("hemi" = "half"), forming hemelytra. There have been a number of different classification schemes in the past, some of which separate the Homoptera (cicadas, aphids, etc.) into their own order, and others which combine the two groups. In this course, I will be using the combined order, Hemiptera.

All members of this order are paurometabolous, and have haustellate, piercing/sucking mouthparts. We will see three suborders in this lab: Heteroptera (true bugs), Auchenorrhyncha (cicadas and hoppers), and Sternorrhyncha (plant parasitic forms).

Heteroptera

The suborder Heteroptera, the true bugs, are so-named because their forewings are partially sclerotized at the base, forming hemelytra. In addition to this distinctive characteristic, the piercing/sucking mouthparts originate at the front of the head: they may point forwards, down, or be tucked up under the body between the forelegs. Some groups are blood-feeders (e.g. bed bugs, kissing bugs) and, thus, very important medically. Several have extremely painful bites (e.g. wheel bugs, giant water bugs, and backswimmers). Superficially, they resemble beetles, but:

- The forewings overlap on the dorsal surface, usually

forming an “X” or “Y” pattern
- They have a large scutellum, a triangular sclerite between the bases of the forewings
- Beetles NEVER have sucking mouthparts

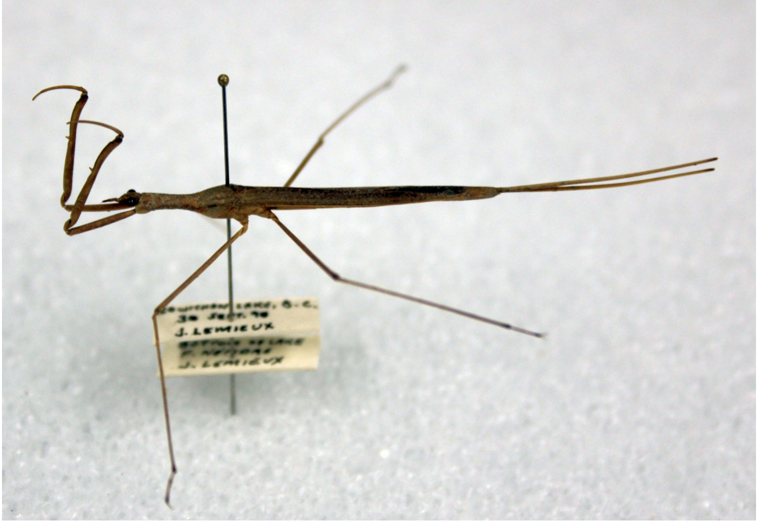
There are many different feeding guilds within this suborder. Some species are exclusively herbivorous, some are predators, and some are ectoparasitic on larger animals. A few are omnivorous, e.g. *Campylomma verbasci*, the mullein bug. It can be a plant pest in some agricultural settings, but also an important biological control agent for other plant pests. Many also have obvious scent glands, which are often more obvious on nymphs. These produce pheromones or defensive compounds, and often smell bad, even to humans.

There are seven infraorders within this suborder. You do not need to know all their names, but they do underlie the sequence in which I will present the most important families for you to know.

49. Hemiptera - Heteroptera - Aquatic Families

Nepidae

An entirely aquatic family, the Nepidae, or water scorpions, can fly as adults to disperse between water bodies. They are slow, underwater predators with two pairs of walking legs. The front pair of legs is modified to be raptorial. Water scorpions also have a long, posterior siphon for breathing air at the surface of the water, giving them their common name.



Belostomatidae

The Belostomatidae are also aquatic. They are large, aggressive predators, with swimming hind legs and raptorial forelegs. Their bite is quite painful so, if you catch one, handle it carefully!

Corixidae

The next two families, the Corixidae and the Notonectidae, look quite similar. The Corixidae, or water boatmen, tend to be smaller than the Notonectidae. Corixidae are mostly detritivores or herbivorous on algae, and have scoop-shaped front legs for gathering food. Water boatmen swim upright, and have a dark notum with a pale or silvery sternum.

Notonectidae

Notonectidae, the backswimmers, are larger than Corixidae, and predatory. They swim upside down and their colouring is reversed: they have a dark sternum and a pale or silvery notum. Like Belostomatidae, they will bite in self-defense.

Gerridae

The Gerridae are commonly known as water striders or water skaters. You have probably seen these insects on the surface of local ponds. All members of this family are surface-dwelling predators or scavengers, with forelegs modified for holding food. They are very sensitive to vibrations (waves) on the surface of the water, and use them to find food and avoid predators. Their tarsal claws are set back from the tip of the tarsus, allowing them to walk on the water without breaking the surface tension. This family also includes the genus *Halobates*, five species of which are pelagic, living on the open ocean.

50. Hemiptera - Heteroptera - Terrestrial Families

Tingidae

Most true bugs are not aquatic. The Tingidae, or lace bugs, are small and gregarious, with evident sculpting on their wings as adults. They are phytophagous on phloem sap, and are sometimes tended by ants.

Miridae

Miridae are small, widely distributed plant feeders. Some, e.g. the *Lygus* bugs, are economically important agricultural pests. They closely resemble some other families in this order, especially the Lygaeidae. The Miridae have a distinctive separate sclerite, called the cuneus, on the outer edge of the forewing, where the leathery part of the hemelytron joins the membranous part. Lygaeidae lack this separate sclerite. The mullein bug, *Campylomma verbasci*, commonly found on campus, is also a member of this family.

Nabidae

The Nabidae, or damsel bugs, are elongate bugs with raptorial forelegs. This adaptation should tell you that they are predatory. Your key distinguishes them as having a broad, flat pad on the femur; this is a very difficult feature to see!

Anthocoridae

The minute pirate bugs belong to the family Anthocoridae.

These are tiny, predatory bugs, and are very important in biological control of pests in greenhouses. They have a distinctive black and white colour pattern on the forewings.

This image is created by user B. Schoenmakers at waarneming.nl, a source of nature observations in the Netherlands., CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons

Cimicidae

Given that Hemiptera all have piercing/sucking mouthparts, and that they rely on a variety of fluid food sources, it should come as no surprise that some members of the order are blood-feeders. The Cimicidae, or bed bugs, are all ectoparasites of vertebrates, and are important pests of humans. Bed bug populations have undergone a resurgence lately, and you should learn how to inspect any new accommodations for signs of bed bugs and how to keep your belongings from becoming infested. Bed bugs can be notoriously difficult to eradicate once they are established.

Bed bugs also have extremely interesting reproductive behaviours. Instead of mating with the female using the genitalia, male bed bugs use a process called traumatic insemination. The sperm are introduced to the female through a hole that the male makes in the female's body wall.

Reduviidae

A second family of Hemiptera of medical importance is the

Reduviidae, or assassin bugs. Members of this family are predaceous, and sometimes have raptorial forelegs. A few are hematophagous. The most important of these are in the subfamily Triatominae, also called the kissing bugs. Species that cohabit with humans vector a parasite, *Trypanosoma cruzi*, which causes Chagas disease. Bites of even the non-hematophagous species of Reduviidae can be extremely painful.

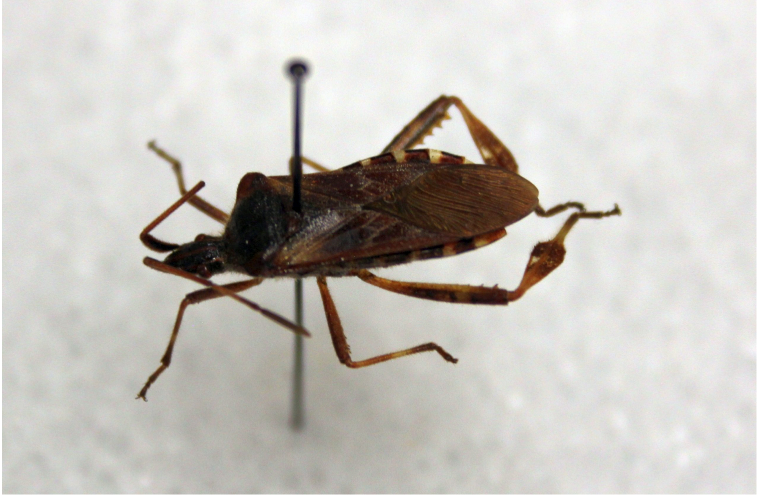
Notice that Reduviidae have a short, three-segmented proboscis that is carried tucked into a small groove between the forelegs. They are often sculpted or prickly, to stay concealed in vegetation as they hunt for prey.

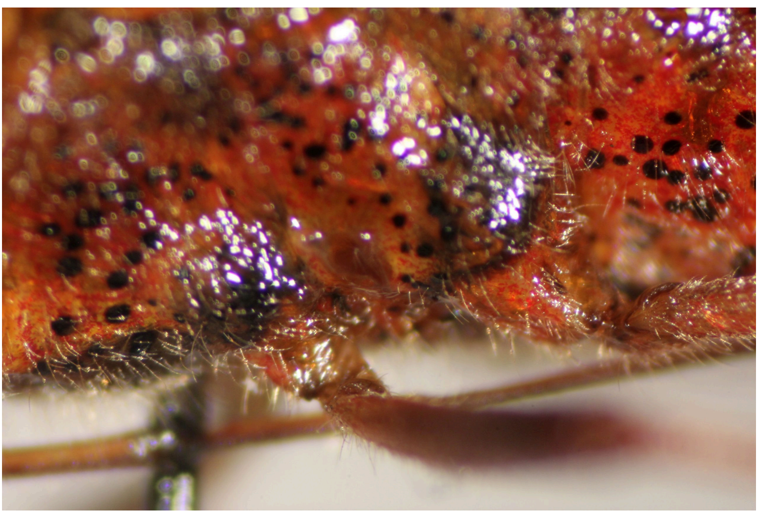
Lygaeidae

Lygaeidae, or seed bugs, are small to medium sized bugs. Some species, especially those that feed on plants that are toxic or distasteful to vertebrates, have bright, aposematic colouration. Most are seed predators, but a few are phytophagous on other plant parts or predaceous They closely resemble Miridae, among other groups, but adults can be easily distinguished from Miridae by the lack of a cuneus in the forewing.

Coreidae

Coreidae, the leaf-footed bugs, often have expanded, leaf-like, hind tibiae. Most are seed predators (e.g. *Leptoglossus* *occidentalis*, the western conifer seed bug). Some species may be phytophagous on other plant parts or even predaceous. They are fairly large, and are often mistaken for Reduviidae, but have a longer proboscis that is not carried in a groove between the forelegs. Some are gregarious, spending the winter in sheltered locations in groups. They have prominent scent glands, and are also sometimes called stink bugs for that reason.





Pentatomidae

Pentatomidae, the stink bugs, have notable defensive secretions and scent glands. They also have a recognizable, pentagonal shape. They look quite similar to the Acanthosomatidae, however, and the only reliable way to differentiate the two families (once you have narrowed the identification to one of these two families) is to count the tarsal segments. Pentatomidae have three-segmented tarsi, while Acanthosomatidae have two-segmented tarsi. Both families are mostly phytophagous, though they can sometimes be predaceous.

Acanthosomatidae

Acanthosomatidae are also known as stink bugs, because they also have prominent scent glands. Another common name is parent bugs, for the degree of parental care they show their offspring. Again, this family is quite similar to the Pentatomidae, and the only reliable way to differentiate the two families (once you have narrowed the identification to one of these two families) is to count the tarsal segments. Pentatomidae have three-segmented tarsi, while Acanthosomatidae have two-segmented tarsi. Both families are mostly phytophagous, though they can sometimes be predaceous. *Elasmostethus cruciatus*, the red-cross shield bug, is commonly collected in Prince George.

51. Hemiptera - Auchenorrhyncha

Auchenorrhyncha

The suborder Auchenorrhyncha was previously part of the suborder (and prior to that a completely separate order from Hemiptera!) Homoptera ("homo" = "same"). Both the Auchenorrhyncha and the third suborder, the Sternorrhyncha, have membranous forewings. Their mouthparts are also attached towards the back of the head (they are opisthognathous) so that the proboscis is held between the forelegs, and can be difficult to see in some specimens. Auchenorrhyncha ("auchenn" = "throat" or "neck", and "rhynch" = "snout") includes the cicadas and various forms of planthoppers.

D.2.1 Cicadidae

Cicadidae are fairly large insects with long life cycles. Most of their lives are spent as nymphs underground, feeding on plant tissues. Some eastern species have 13- to 17-year life cycles, only emerging as adults for a few weeks during that period. To maximize reproductive success, these multi-year life cycles are tightly synchronized so that all individuals of one species emerge within the same year, and within a couple of weeks. Adult cicadas stridulate to attract mates, and their shrill buzzing sounds can be heard on hot summer days around Prince George. Eggs are laid in small notches cut in twigs, and these can be problematic during large emergences.

Membracidae

Membracidae, or treehoppers, have an impressive diversity of pronotal shapes and ornamentation, evolved to make them look more like the woody plants on which they feed. These are rarely collected by students, probably because they are so cryptic.

Cercopidae

The spittle bugs, Cercopidae, are responsible for the frothy "frog spit" often encountered in long grass and on other vegetation in the summer. The nymphs use the froth as a protective covering while they feed on the plants. These are common in Prince George, and resemble miniature cicadas in body shape. They closely resemble the next family, Cicadellidae. Cercopidae tend to have stouter bodies and very short, bristle-like antennae compared to Cicadellidae. The definitive characteristic is the bristles/spines on the hind tarsi: Cercopidae have a ring of stout spines at the distal ends of the hind tibiae and each hind tarsal segment. There may also be one or two stout spines elsewhere on the hind tibiae.

Cicadellidae

Cicadellidae also resemble miniature cicadas and, of course, Cercopidae. Their bodies tend to be slenderer and their antennae longer than Cercopidae. The hind tibiae have rows of bristles along them, in contrast to the stout bristles seen in Cercopidae. This family is also common in Prince George, and feeds on plant sap.

Fulgoridae

While we do not yet have any specimens of Fulgoridae at UNBC, it is a family that you should be aware of. They are important plant-feeders, especially in the tropics and subtropics. Recently, one species native to China, Bangladesh, and Vietnam, has been unintentionally introduced to Japan, Korea, and the USA. The spotted lanternfly, *Lycorma delicatula*, was detected in Pennsylvania in 2014. It is a large (~2.5 cm), brightly coloured insect that poses a threat to grapes, hops, fruit trees, and forest trees. The nymphs are also brightly coloured and gregarious.

SLF-spotted lanternfly (Lycorma delicatula) winged adult 4th instar nymph (red body) in Pennsylvania, on July 20, 2018. USDA-ARS Photo by Stephen Ausmus.

SLF-spotted lanternfly (Lycorma delicatula) adult winged, in Pennsylvania, on July 20, 2018. USDA-ARS Photo by Stephen Ausmus.

52. Hemiptera - Sternorrhyncha

Sternorrhyncha

The last suborder of Hemiptera that we will cover in lab is Sternorrhyncha ("sterno" = "chest", "rhynch" = "snout"). These insects all have piercing/sucking mouthparts that originate far back on the underneath of the head. All are small, soft-bodied, quite delicate, and are, therefore, best preserved in ethanol. In winged forms, both front and hind wings are membranous. The suborder includes many serious plant pests and vectors of plant pathogens. There are many species with highly coevolved symbiotic relationships, especially with ants.

Psyllidae

Psyllidae are also called jumping plant lice. They often have very highly coevolved relationships with their plant hosts, and many are thought to be monophagous.

Aleyrodidae

Aleyrodidae, or whiteflies, are important pests in greenhouses. Most are only ~1-2 mm long, allowing them to pass through even fine screening. In some cases, the mesh size will effectively exclude whitefly predators and parasites. They have a modified life cycle with a sessile "pupa" stage. We do not have an intact specimen in the collection.

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Aphididae

A large, easily recognizable family, the Aphididae includes all of the aphids. Aphids are very important plant pests in many settings, and vector a number of plant pathogens. Many aphids reproduce parthenogenically during periods of good environmental conditions. As environmental cues indicate that conditions are worsening, they start to produce males, mate, and produce overwintering stages. Many of the parthenogenic females lack wings, while males and some females are winged. Female aphids are also often capable of giving birth to live nymphs that may, at the moment of their birth, already be forming the next generation in their ovarioles. Needless to say, population fluctuations can be dramatic!

Aphididae all have cornicles, which project from the posterior abdomen. They function to secrete defensive compounds, and may be flush with the abdomen or project quite a distance.

Adelgidae

Adelgidae are often called “woolly aphids”, but are in a separate family (or subfamily in some phylogenies) from aphids. The correct common name is woolly adelgids. Unlike aphids, adelgids do not have projecting cornicles, and they never give birth to nymphs. Several Adelgidae (e.g. the balsam woolly adelgid, *Adelges piceae*) are important pests of forest trees. They often have complex life cycles, involving more than one host and several generations with different forms and ecologies. Pictured below are the galls of *Adelges cooleyi*, the Cooley spruce gall adelgid, on hybrid white spruce, and a different life stage of the same insect on Douglas-fir.

Superfamily Coccoidea

The last group of Hemiptera we will distinguish only to the superfamily level, the scale insects, or Coccoidea. Even the ranking of this taxon is somewhat uncertain. Coccoidea includes a number of families, all of which have similar characteristics. Adult females are almost always sessile and covered in a waxy dome or other wax covering. Some even live in soil. Males are usually winged, and some species may be partially or exclusively parthenogenic. Newly-hatched nymphs, or crawlers, can disperse to new plants.

Scale insects can be, as you might expect, important pests of plants in various settings. They have also been important to humans for various other reasons. For example, *Kerria lacca*, the lac insect, has been cultivated for production of lac resin, from which we derive lacquer. Another economically important scale insect is *Dactylopius coccus*, which feeds on *Opuntia* spp., prickly pear cactus. For a very long time, this insect was a primary source of true red fabric dye, a highly valued colour.

Scale insects on the stem of Cornus sanguinea: Gilles San Martin from Namur, Belgium, CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0>, via Wikimedia Commons

Dactylopius coccus, Dick Culbert from Gibsons, B.C., Canada, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons.

PART VIII

LAB 6: NEUROPTEROID ORDERS

53. Introduction

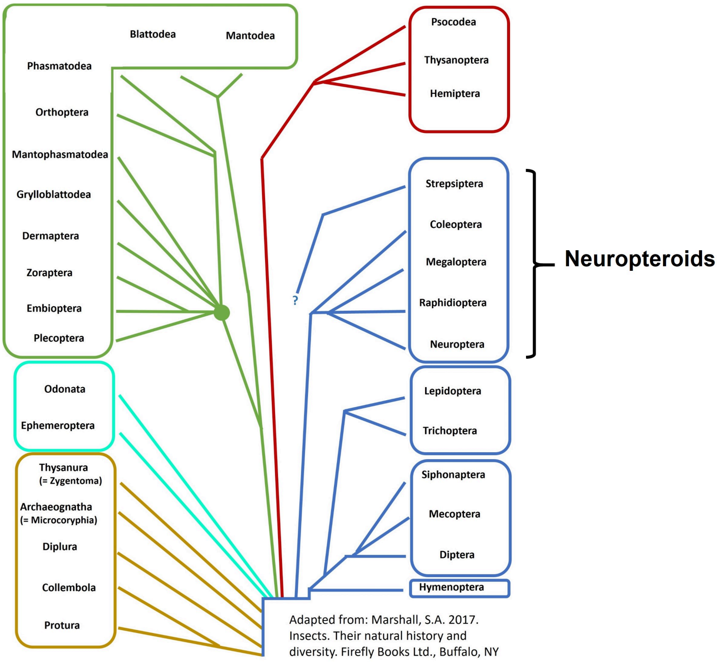
Introduction

In this lab, we will cover the neuropteroid orders, which consist of four relatively small orders and one enormous order. As always, I will emphasize those taxa found in northern BC. Your goal is to learn how to identify various common insects to order and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

The neuropteroids include five orders of insects:

- Neuroptera, including the lacewings, antlions, and mantisflies;
- Megaloptera, the alderflies, dobsonflies, and fishflies;
- Raphidioptera, the snakeflies;
- Strepsiptera, the twisted-winged parasites;
- and Coleoptera, the beetles

If your collection includes families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know! If you are having difficulty seeing what the key asks for, or you aren't sure what a photo shows, please ask, or arrange a time to visit the lab and observe the insects in person.



Adapted from: Marshall, S.A. 2017. Insects. Their natural history and diversity. Firefly Books Ltd., Buffalo, NY

54. Neuroptera

Neuroptera

The order Neuroptera (“neuro” = “nerve”, or “net”) includes the lacewings, antlions, and mantisflies. This is the first truly holometabolous order that we will see in lab. It is a fairly heterogeneous group, but all adults are characterized by a network of veins on the wings.

Chrysopidae

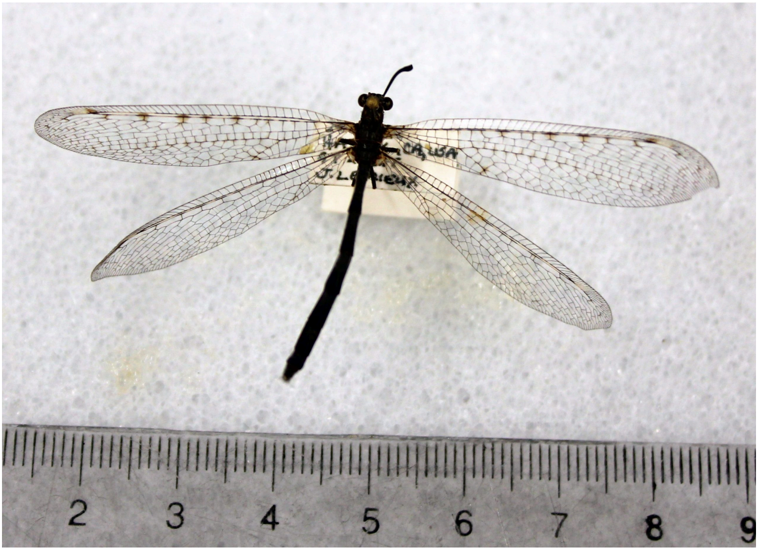
The green lacewings, Chrysopidae, are predaceous as both adults and larvae. Stalked eggs are common in this family, presumably to reduce cannibalism when the eggs begin to hatch. Larvae have hollow mandibles that are modified for sucking fluids from their prey. The adults are relatively slow, delicate, “fluttery” fliers. Most are preserved in ethanol, as they do shrivel, but adults can be pinned. True to their name, most adult lacewings are greenish. An adult and a larva are pictured. Notice that the costal veins, along the leading edge of the forewing, are simple and not forked.

Hemerobiidae

The brown lacewings, Hemerobiidae, are quite similar to the Chrysopidae, and have a similar biology. Adults tend to be brownish, with setae on their wings. The costal veins are forked, however, making it reasonably easy to tell these two families apart.

Myrmeleontidae

Myrmeleontidae, the antlions, burrow in loose, sandy soil as larvae. When insects, such as ants, encounter the steep-sided burrow, they get caught in tiny landslides, and end up at the bottom of a funnel-shaped pit. At the bottom, the larval antlion is waiting to eat them. We have a couple of adult antlions in the collection, but no larvae. Notice the prominent, clubbed antennae.



Mantispidae

Mantispidae, the mantisflies, are very strange looking insects. They have the characteristic net-veined wings of all Neuroptera, an elongated prothorax, and raptorial front legs that resemble those of a mantis. Some Mantispidae have larvae that feed on spider eggs in the egg sac of the spider. Adult females must find the spider eggs, and one way they do that is to hitchhike on a female spider, usually a wolf spider.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55. Megaloptera

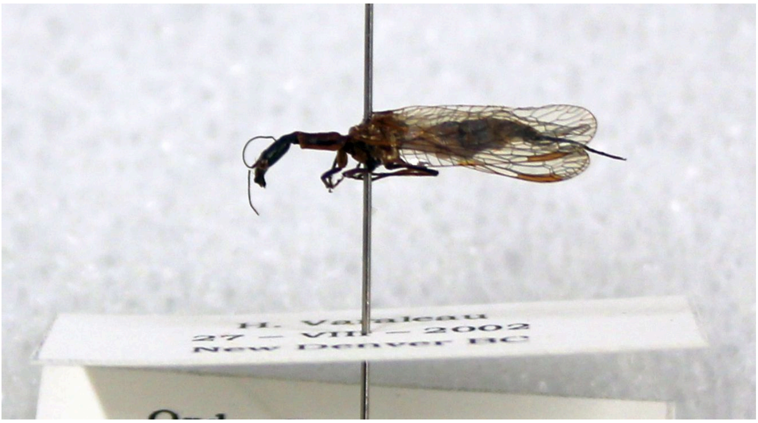
Megaloptera

Megaloptera includes the alderflies, dobsonflies, and fishflies. All members of the order have large wings that are somewhat net-veined. Their larvae are aquatic, mostly in streams, and have gills along the abdomen. The larvae tend to have large mandibles as well, as they are predaceous. They are also an important food source for predatory fish.

56. Raphidioptera

Raphidioptera

The snakeflies, Raphidioptera, are another odd-looking group of insects. They are somewhat similar to mantisflies, but do not have raptorial forelegs. All snakeflies are predatory, and the larvae are mostly found under bark. They are relatively common in dry Douglas-fir forests south of here, and are found at least as far north as Quesnel and possibly Prince George.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57. Strepsiptera

Strepsiptera

The last of the small neuropteroid orders that you should know is the Strepsiptera, also known as the twisted-winged parasites. This entire order is endoparasitic in other insects, including throughout most of their adult lives. Very young larvae and males are the only free-living life stages. Most parasitize Hymenoptera, but a few parasitize cockroaches and some other insects. The adult female is larva-like, and protrudes from between the sclerites of the host. The male is winged, but has only a single pair of wings. The forewings are reduced and resemble the halteres of Diptera. The male's eye is not compound; instead, there is a cluster of eyes resembling a blackberry.

We do not have any Strepsiptera in the collection at UNBC.

Duane D. McKenna , Brian D. Farrell, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons

Lasioglossum w Strepsiptera Specimen ID: 0358 Sex: Female Size: 6 mm Collection Location: USA, WI, Bayfield County. Apostle Islands National Lake Shore. Boreal woodland along Mawike Road. WGS84 46.8874N/-91.0408W Plot: AI-3 Collection Date: 1-Aug-2014 Collector: Brick M. Fevold Halictidae; Halictinae; Halictini; Lasioglossum cf. subgenus Dialictus. Twisted-wing parasite (Order Strepsiptera) between metasomal tergites 4 and 5. No other Strepsiptera observed in 2013-2014

bee/wasp samples. Detail of Strepsipteran (4). Branched setae, characteristic of bees, are also visible on the abdomen.	maxson.erin, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons

58. Coleoptera - Introduction

Coleoptera

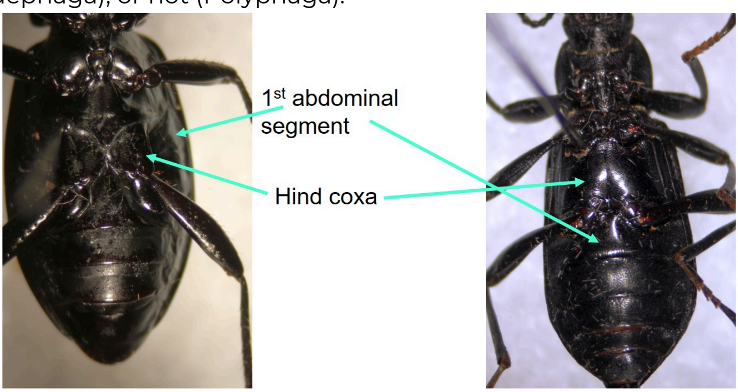
The largest neuropteroid order, and the largest order of all insects at the current time, is Coleoptera ("coleo" = "sheath"), the beetles. About one-third of all described animal species are beetles. There are approximately 350,000 beetles described, with ~30,000 species in North America. There is even an entire professional society dedicated to the study of beetles, called the Coleopterists Society. It would be impossible to cover the many families of beetles in a single lab, but we will address a few of the most important families, with an emphasis on those found in northern BC.

All beetles are holometabolous and mandibulate, and have the forewings modified into elytra. These hardened forewings serve as protection for the membranous hindwings, helping beetles access some cryptic habitats. You will see one family, the Staphylinidae, that have reduced elytra that do not cover the entire abdomen; however, many species in this family can still fly. They fold up their hindwings even more than usual to keep them under their shortened elytra.

Beetle larvae are extremely variable. Some are grub-like, while others are highly mobile. Some have large, distinct heads, while in others the head is barely visible. Some are active, prognathous predators. Make sure that you pay attention to the variety of larval forms.

Beetles come in an enormous range of sizes, from the tiny feather-winged beetles at ~0.3-4.0 mm, up to the hand-sized harlequin beetles, goliath beetles, and stag beetles at up to 152 mm or more. Feather-winged beetles have fringed hindwings like thrips, and are small enough that they essentially swim through the air.

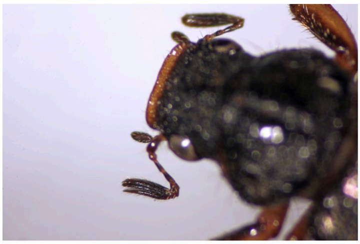
Coleoptera is divided into four suborders: Adephaga, Archostemata, Myxophaga, and Polyphaga. You will encounter specimens of two of these suborders, Adephaga and Polyphaga, in this lab, and could encounter a third, Archostemata, in your collections. Adephaga and Polyphaga are distinguished based on the position of the hind coxae relative to the first abdominal segment. It may take a little practice to learn to recognize this characteristic but, once you learn, it is infallible. Start by looking at the ventral side of the beetle. You will need to decide whether the hind coxae lie across the hind margin of the first abdominal segment (Adephaga), or not (Polyphaga).



Adephaga: Hind coxae cross hind margin of first abdominal segment

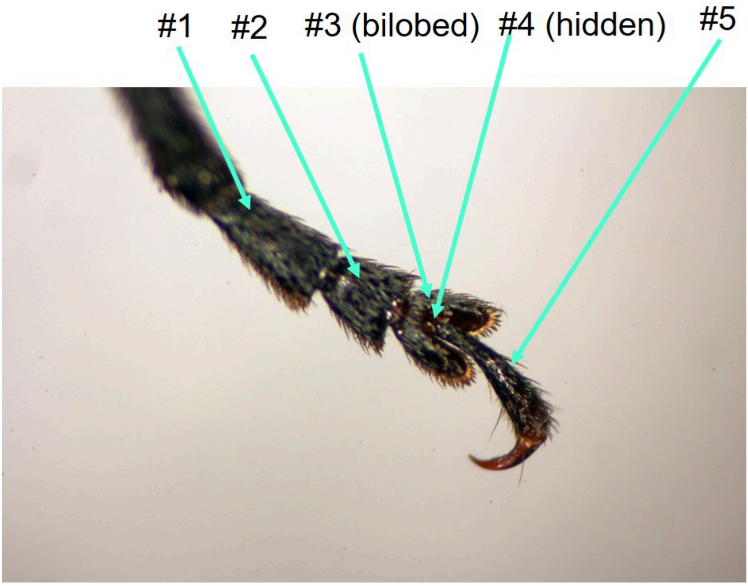
Polyphaga: Hind coxae do not cross hind margin of first abdominal segment

Other key characteristics that will help you distinguish between the many families of beetles include the antennal shape. Antennae may be lamellate, consisting of finger-like projections on one side of the antenna's tip, filiform, which means all segments of the antenna are about the same width, or clubbed, meaning that the last few segments are enlarged to form a much wider area of the antenna. Here are some examples of those three forms.



At some point when you are trying to identify a beetle to family, you will almost certainly encounter a “tarsal formula”. Beetles may have different numbers of tarsal segments on the front, middle, and hind legs. Different keys express this formula differently, with some simply saying, e.g. “tarsi 5-5-4”. That would tell you that there are five tarsal segments on the front legs, 5 on the middle legs, and four on the hind legs, as illustrated below. Other combinations are also possible.

One last point to note about tarsal segmentation: some families of beetles are described as having “apparently” three- or four-segmented tarsi! In the case of a beetle with five tarsal segments, for example, the third segment (counted from the base of the tarsus, nearest the tibia) may be bilobed and expanded, with the fourth segment hidden or nearly hidden in between the two lobes. If you are counting quickly and not careful, you may think that the tarsus shown below has four segments when, in fact, it has five. The fourth is very small, tucked away between the lobes of the third tarsomere, and easily missed.



59. Coleoptera - Adephaga

Adephaga

Adephaga is the smaller of the two Coleoptera suborders that we cover in the lab. Remember that all of these beetles have the first abdominal segment divided by the hind coxae. We will cover only four families within Adephaga, but there are several more that you could encounter in your collections.

Carabidae

One family that you will almost certainly encounter in your collections is Carabidae, the ground beetles. Carabidae are mostly active predators as both adults and larvae, although there are some species that are herbivorous seed predators. They range from extreme specialists to broad generalists, and can be sensitive bioindicators of disturbance in ecosystems.

Cicindelidae

At various times in the past, Cicindelidae, the tiger beetles, have been grouped as a subfamily of the Carabidae or as a separate family. Currently, they are considered a separate family. Tiger beetles are very active predators, frequently hunting in very open habitats. They run and fly short distances in search of prey, making them challenging to catch. Notice the large, prognathous mandibles and large eyes. Many adults are iridescent and colourful. some species are endangered, mostly due to habitat alteration and loss.

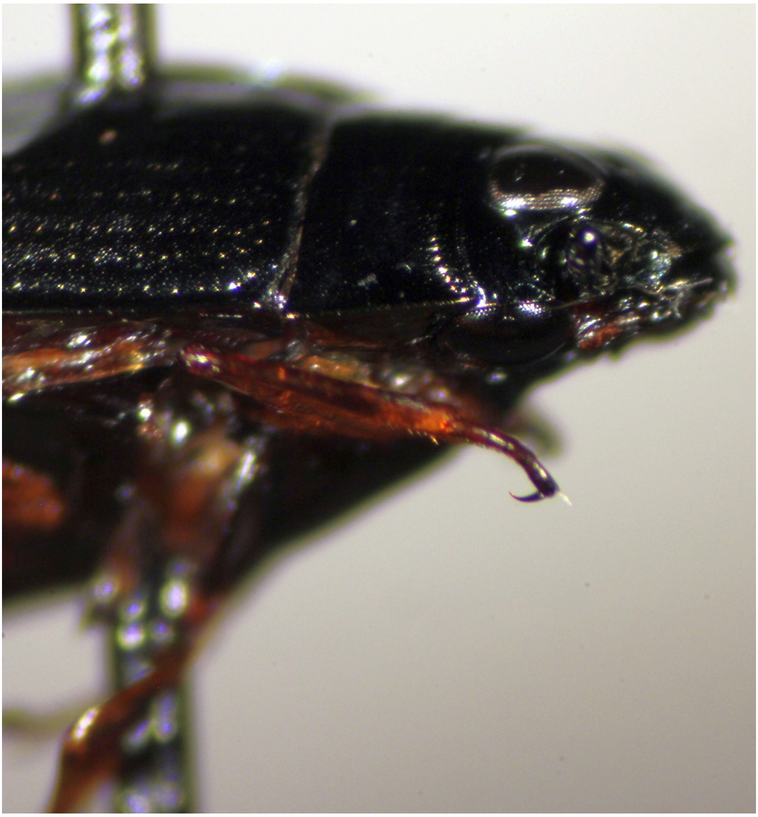
Cicindelidae larvae usually live in tunnels, with their heads and mandibles resting flush with the ground. This habit allows them to grab passing insects and other prey. They are fluid-feeders, crushing their prey and secreting digestive enzymes to break it down.

Dytiscidae

Several families of beetles are aquatic. Dytiscidae, the predaceous diving beetles, are aquatic as both larvae and adults. Their hind legs are flattened and fringed with hairs that allow them to swim efficiently. They do not have gills; instead, they swim to the surface periodically and trap an air bubble under the elytra or in body hairs. They then dive again with the bubble attached. Males can be distinguished as their fore tarsi are modified into suction cups to help hold the female during mating. Larvae are also active predators, known as water tigers.

Gyrinidae

The last family we will cover in Adephaga is Gyrinidae, the whirligig beetles. These beetles are also aquatic as larvae and adults, and are also predatory. Adult whirligig beetles live on the surface of the water, and swim in random patterns when they are disturbed. They can also dive. Their eyes are split into two parts. One part is above the surface of the water to detect prey and predators coming from above, while the other part is below the surface of the water to detect food or threats from below. Whirligig beetles also have scent glands, as you may notice if you catch one.



60. Coleoptera - Polyphaga I

Polyphaga

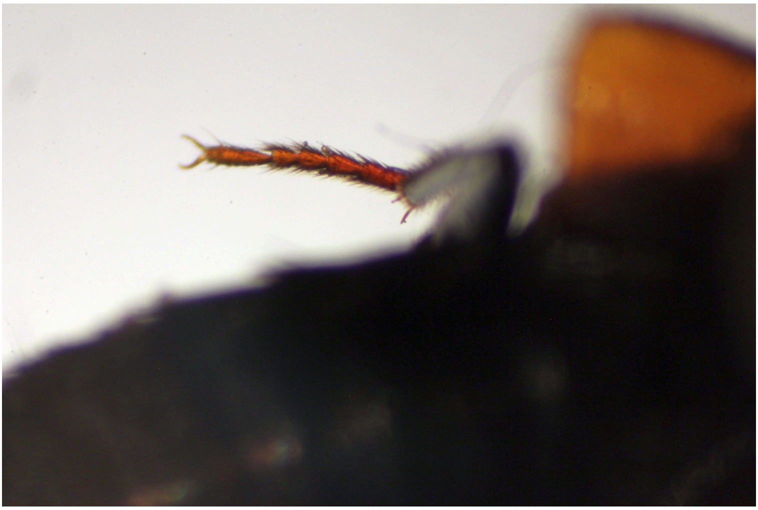
Polyphaga is the largest suborder of beetles, and includes the vast majority of the order. We will cover a number of the most common families found in northern BC, but you will have to key the specimens that you plan to submit in your collection assignment very carefully. Make sure you review the features that distinguish Adephaga from Polyphaga.

Silphidae

Silphidae, or carrion beetles, are not uncommon in student collections. The most commonly collected species have orange markings on their black elytra. We have also collected some with black, ridged, soft-looking elytra in Prince George in our pitfall traps. Note the clubbed antennae, short elytra that do not completely cover the abdomen, and five-segmented tarsi. These beetles often have phoretic mites attached. The mites "hitchhike" on the beetles to reach new carrion food sources.

Staphylinidae

Staphylinidae, or rove beetles, is another family with short elytra that do not cover the entire abdomen. Rove beetles are also often associated with carrion, but are a diverse group with many feeding strategies. Rove beetles also have five-segmented tarsi; their short elytra will usually provide you the first clue to their identity. When you are collecting, note that some species will curl the tip of their abdomens up to mimic stinging.



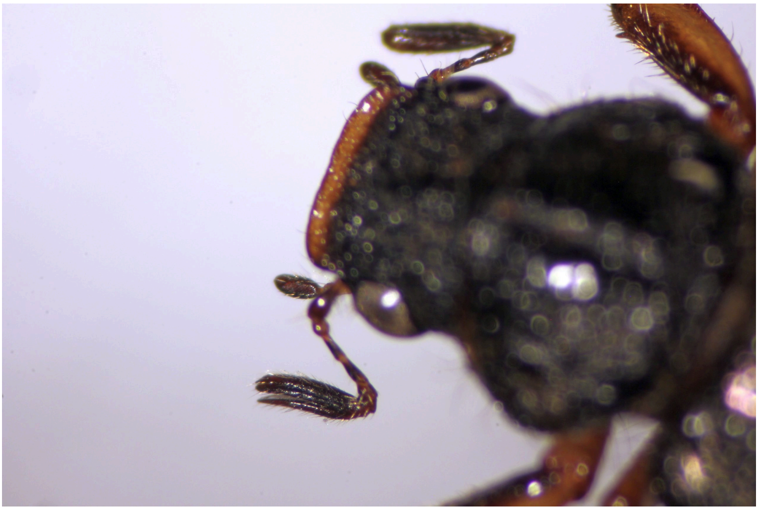
Lucanidae

Lucanidae are the stag beetles. We have some in the collection, but none are available for you to key. Male beetles (but not the females) have large, modified mandibles, which they use in dominance displays such as wrestling matches.

You should be able to distinguish these from the next family, Scarabaeidae.

Scarabaeidae

Scarab beetles, in the family Scarabaeidae, include a diverse assortment of beetles: rhinoceros beetles, goliath beetles, dung beetles, and June beetles are all members of this family. Many are large, shiny, and/or brightly-coloured. They are herbivorous, with the larvae usually feeding on roots. Some groups are, therefore, important plant pests. In the photos, you should be able to see the five-segmented tarsi and the characteristic lamellate antennae. I have also included a photo of the BC species of rhinoceros beetle (not large, but still a rhinoceros beetle!)



Buprestidae

Buprestidae have a number of common names, including metallic woodborers, flat-headed woodborers, and jewel beetles. As you might expect, many members of this family have showy, bright, metallic colouration, some more dramatic than others. Their elytra have been used in jewelry and in textiles as ornamentation. Adults lay their eggs on the bark of dead and dying trees and, when the larvae hatch, they spend some time feeding in the cambium. They then bore into the sapwood and heartwood. The thoracic segments of the larvae are dorsoventrally flattened, leading to the name flat-headed borers. Several species are pyrophilic, ovipositing in fire-killed or damaged trees. Some are important pests of wood, especially wood in service. Very long larval life-spans are possible, leading to the emergence of adult beetles from e.g. furniture up to 50 years after the wood was harvested. Adults have a characteristic elliptical body shape, and are also elliptical in cross-section. When they emerge from the wood where they pupated they leave a diagnostic elliptical emergence hole. They can be easy to confuse with the next family, Elateridae, and a few other families that we do not cover in this course.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6 Elateridae

Elateridae are the click beetles. Their body shape is similar to that of Buprestidae. Most Elateridae are characterized by having a sclerotized spine on the underside of the prosternum that fits into a notch on the mesosternum. If the beetle ends up on its dorsal surface, this spine can be forcibly snapped out of the notch, producing an audible “click”, and propelling the beetle into the air. Buprestidae lack this peg. The posterior corners of the pronotum are usually extended backwards into points in Elateridae, but not in Buprestidae. Most Elateridae are phytophagous as adults, but may be phytophagous, saprophagous, or even opportunistic predators as larvae. A few species, called “wireworms”, are significant agricultural pests as larvae.

Lampyridae

Lampyridae are called lightningbugs or fireflies. Fireflies use luciferins, which are small, heterocyclic compounds, to produce "cold" light. The light is produced through enzyme-catalyzed oxidation, and an unstable, intermediate produce emits photons as it decays to its ground state. The light produced has no infrared or ultraviolet wavelengths. Some species use light to attract mates, and some even synchronize the flashes of light they produce. In one genus, females mimic the flash patterns of other species to lure in and eat those males. As larvae, they are distasteful to most predators, so larvae sometimes glow as a warning. We do have Lampyridae in northern BC, although most are non-luminescent species. They are characteristically quite dorsoventrally flattened beetles, with soft elytra and a flat, expanded pronotum that conceals the head from above.

Dermestidae

Dermestidae, the skin beetles, are very important pests of stored animal products. They are, essentially detritivores that specialize on decaying animal material. They are also important pests in natural history museums, and can significantly damage insect, bird, and mammal specimens in particular. One species is used (with caution!) to clean skeletons, as both larvae and adults will consume all of the flesh, leaving behind clean bones. Dermestidae are very common here, especially the larder beetle, *Dermestes lardarius*. The hairy larvae of this insect are frequently found in kitchens and bathrooms feeding on scraps of food and skin. Adults have clubbed antennae, often hidden underneath the pronotum. We also have a small, roundish species, *Anthrenus verbasci*, the varied carpet beetle.

Ptinidae

Ptinidae includes cigarette beetles, drugstore beetles, spider beetles, and death-watch beetles. There are a number of important pests of stored plant products and wood, as you might have guessed from the common names. In the past, portions of this family have been called Anobiidae. Ptinidae is the current name, but it refers to a quite diverse collection of beetles. They seem to have few good, unifying characteristics, and will key out at several locations in your text.

Spider beetle (Katja Schulz, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons).

A death-watch beetle (Katja Schulz from Washington, D. C., USA, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons).

61. Coleoptera - Polyphaga II

Cleridae

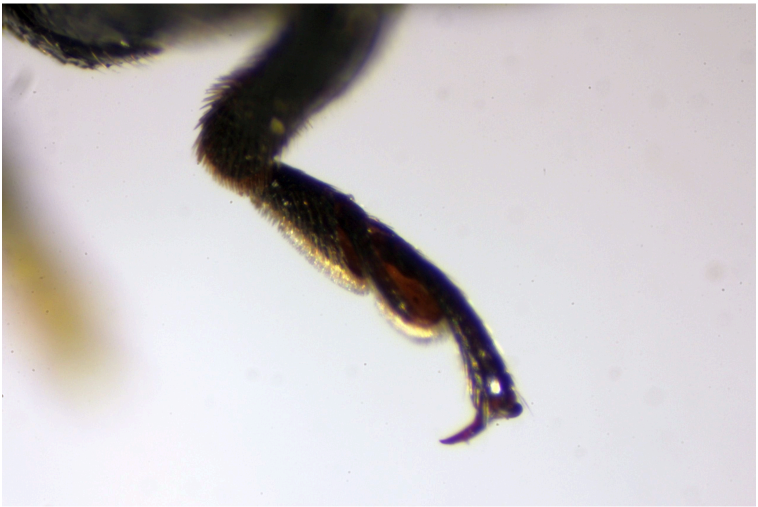
Cleridae, the checkered beetles, have a characteristic colour pattern and are fairly hairy beetles, although there is some variation within the family. Both adults and larvae are very important predators of bark beetles. Adults have a narrow prothorax. Each elytra forms a sharp angle just behind the pronotum, giving the beetle the appearance of wearing “shoulder pads”.

Cucujidae

The flat bark beetles, Cucujidae, are also voracious predators of bark beetles. They are elongate, dorsoventrally flattened, and the elytra can be almost parallel-sided. Adults are also often reddish in colour. The tarsal formula is 5-5-5 in females, but 5-5-4 in males.

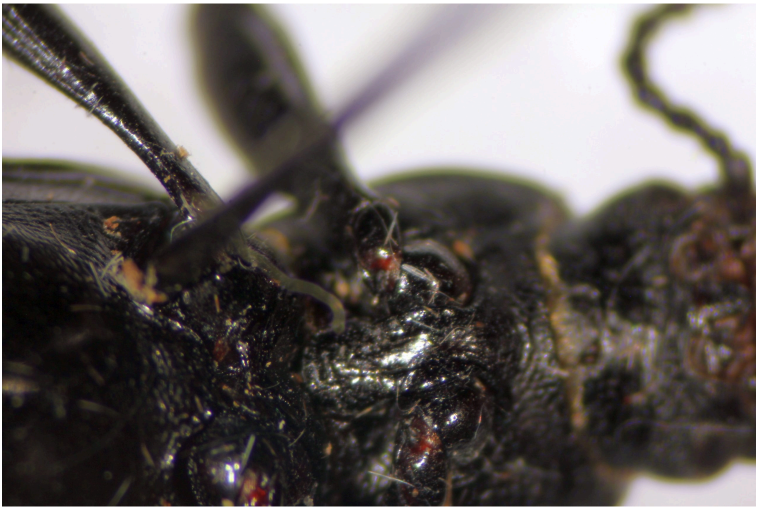
Coccinellidae

Coccinellidae are the ladybird beetles, or “ladybugs”. They are rounded, convex beetles with clubbed antennae, often hidden beneath the pronotum. The tarsal formula is 4-4-4, but count carefully! Segment three is small and hidden between the lobes of segment 2. Both larvae and adults are voracious predators, especially of soft-bodied insects like aphids. Coccinellidae are frequently used as biological control agents in greenhouses and gardens. They have defensive scent glands to help repel predators, as you may notice if you handle them.



Tenebrionidae

The darkling beetles, Tenebrionidae, include beetles with a diverse range of body shapes and biology. You may be familiar with the larvae, which are sold as mealworms for the pet trade. The family also includes some desert-inhabiting beetles, well-known for using their elytra to collect condensation for drinking. A local species is often mistaken for a ground beetle – be sure to check whether the hind coxae cross the hind margin of the first abdominal segment or not! The tarsal formula is 5-5-4, and a hind tarsus is pictured below. You may also encounter a question in some keys, asking whether the front coxal cavities are "closed" or "open". If it looks like the cavity where the front coxa is inserted is complete, and wraps around behind the coxa, it is "closed". If the cavity looks incomplete, and doesn't wrap around the entire base of the coxa, then it is "open".



Meloidae

Meloidae are also known as the blister beetles. Most members of this family produce an irritant compound called cantharidin as a defense. Cantharidin is poisonous, and causes blistering of the skin and a generalized inflammatory response, including swelling and increased blood flow. The compound has been used by humans to treat warts, and has also gained notoriety under the name “Spanish fly”, much touted as an aphrodisiac.

Some species of blister beetles are hypermetamorphic. Hypermetamorphosis is a variant of holometabolous development in which some larval instars are morphologically and ecologically distinct from others. In a typical hypermetamorphic Meloidae life cycle, the first instar is campodeiform (resembling a family of Diplura), mobile, and known as a planidium or triungulin. It lives on plants until it finds a bee or a grasshopper (depending on the species), to which it attaches to be carried back to host’s eggs. It then moults to a legless grub, and feeds on eggs or larvae and on the honey and pollen stored by the bee.

Adult beetles sometimes have shortened elytra, and are often metallic. The tarsal formula is 5-5-4, and the tarsal claws are each split into two. They tend to have a narrow pronotum.

Cerambycidae

Cerambycidae are called round-headed borers or long-horned beetles. Their habits and habitats tend to be similar to those of Buprestidae, as this family also contains wood-boring beetles. The adults tend to be rounder in cross-section, whereas Buprestidae are elliptical, and adult Cerambycidae mostly have extremely long antennae. As you might expect of an insect that lives inside wood as a larva, and then exits the wood as an adult, they often have large, heavily sclerotized mandibles. Some species will also use those mandibles in self-defense – so be careful when handling live specimens! A few species also produce sound, through stridulation, as a defensive tactic. If you catch a large specimen, it is not unusual to hear a squeaking sound from the net. The tarsal formula for these beetles is 5-5-5 but, at first glance, they appear to be 4-4-4. Note the strongly lobed third tarsal segment, which almost completely conceals the fourth segment. Also note that the compound eyes on some species can appear to wrap around the base of the antennae, or may even be completely divided by the antennal bases.


4
5
6
7

Chrysomelidae

Chrysomelidae includes the leaf beetles, as well as the tortoise beetles and flea beetles. This is a large, diverse family of about 55,000 species. Many significant pests of agricultural crops, e.g. the Colorado potato beetle, *Leptinotarsa decemlineata*, are in this family. In addition to the direct damage to plants caused by beetles feeding on their leaves, some species in this family are known or thought to transmit plant viruses and other pathogens.

The tarsal formula, like that of the Cerambycidae, is actually 5-5-5, but often apparently 4-4-4. Many Chrysomelidae closely resemble Coccinellidae (actually 4-4-4, but apparently 3-3-3!), both in body shape and even in colouration, so this trait will help you to distinguish the two families. Chrysomelidae lack the long antennae of Cerambycidae, and they do not have compound eyes that are divided by or wrap around the antennal bases. They also lack a “snout” or elbowed antennae, which distinguishes them from most of the Curculionidae. Many species are metallic or brightly-coloured.

Curculionidae

We have reached the last of the beetle families we will cover in this course, the Curculionidae, also known as the snout beetles or weevils. The family as a whole is characterized by having the head prolonged into a snout, with mandibles at the tip of the snout, and elbowed antennae. Weevils are herbivorous, and many species prey on seeds; this habit has made them major pests of agricultural crops and stored products. The snout is useful for this particular feeding style, as the weevil is able to chew a hole into a hard seed coat, then insert the snout into the hole and feed on the seed and endosperm.

This is an enormous family, with plenty of variation and diversity. Most can be readily identified on sight as weevils by the snout and the elbowed antennae.

But wait! … there's more! Molecular work has determined that a group that was formerly known as a separate family, the Scolytidae, should actually be grouped as a subfamily of the Curculionidae. Now called the Scolytinae, this subfamily includes a multitude of bark beetles. These insects feed on tree phloem as larvae, and spend almost their entire lives underneath the bark of a single tree. They usually feed on dead, dying, or weakened trees with low defensive capabilities. Some species, e.g. mountain pine beetle, *Dendroctonus ponderosae*, can mass attack healthy live trees and kill them. Many are associated with symbiotic fungi, and carry spores in specialized structures called mycangia. The fungi can help to kill the host trees by blocking the xylem elements, and the larval and adult beetles may also feed on the fungus (e.g. ambrosia beetles).

Confusingly, while they are grouped as a subfamily of Curculionidae, Scolytinae lack a prolonged snout, although they do have a broad "muzzle" and elbowed antennae. Scolytinae are small, and have a characteristic elongate, cylindrical body shape, which can help you to identify these beetles. The pronotum often almost hides the head.

PART IX

LAB 7: MECOPTEROID ORDERS I

62. Introduction

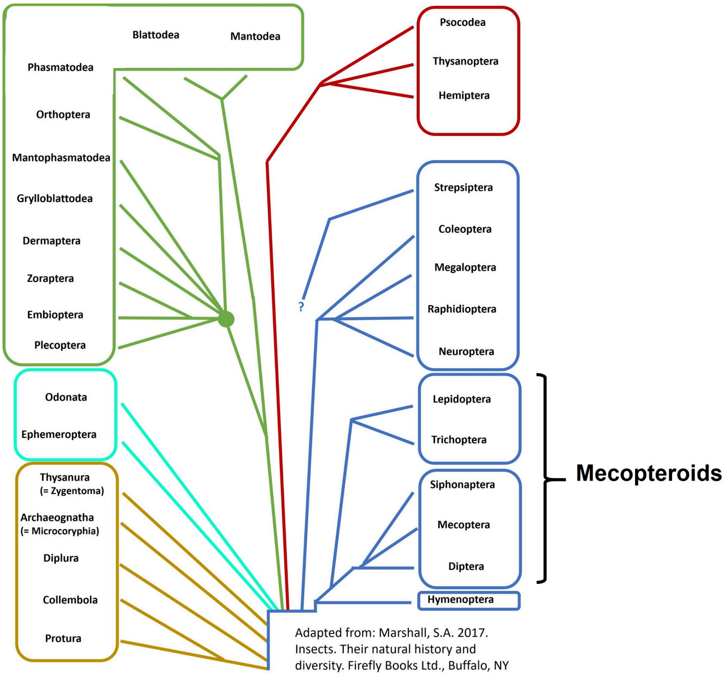
Introduction

The mecopteroid orders are the second last group we will cover, as always with an emphasis on those taxa found in northern BC. The group includes a some large and ecologically important orders, so we will split the mecopteroid orders over two separate labs. Your goal is to learn how to identify various common insects to order and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

The mecopteroids include five orders of insects:

- Trichoptera, the caddisflies;
- Lepidoptera, the butterflies and moths;
- Siphonaptera, the fleas;
- Mecoptera, the scorpionflies;
- and Diptera, the true flies.

We will look at the first two orders in this lab, and the last three orders in the next lab. If your collection includes orders or families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know!


Blattodea
Mantodea
Phasmatodea
Orthoptera
Mantophasmatodea
Grylloblattodea
Dermaptera
Zoraptera
Embioptera
Plecoptera
Odonata
Ephemeroptera
Thysanura
(= Zygentoma)
Archaeognatha
(= Microcoryphia)
Diplura
Collembola
Protura
Psocodea
Thysanoptera
Hemiptera
Strepsiptera
Coleoptera
Megaloptera
Raphidioptera
Neuroptera
?
Lepidoptera
Trichoptera
Siphonaptera
Mecoptera
Diptera
Hymenoptera
Mecopteroids
Adapted from: Marshall, S.A. 2017.
Insects. Their natural history and
diversity. Firefly Books Ltd., Buffalo, NY

63. Trichoptera

Trichoptera

The first mecopteroid taxon we cover is the Trichoptera (“tricho” =- “hair”), or caddisflies. Adult Trichoptera have wings that are covered in hairs, rather than scales. The wings are folded over the back in a tent-like shape; in other words, angled downwards across the dorsal surface. Most adults also have long antennae. Larvae are aquatic in ponds or streams. Many species build cases out of small sand or gravel particles, or out of other detritus. Still other species build silken nets across gaps between stones to intercept debris and prey items that are caught in the current of streams, while others are entirely free-living.

Trichoptera, along with Ephemeroptera and Plecoptera, are used as important bioindicators of unpolluted (by organic materials) streams, especially where EPT (Ephemeroptera, Plecoptera and Trichoptera) constitute a significant proportion of the fauna. Larger numbers tend to be found in cool, oxygen-rich streams. They are also important as food for fish and birds.

64. Lepidoptera - Introduction

Lepidoptera

The second mecopteroid order we cover in this lab is Lepidoptera ("lepido" = "scale"). This order is characterized by having the wings at least partially covered by scales. Larvae are mandibulate, but most adult forma have very reduced mouthparts. In most cases, only the galea of the maxilla remains, and it is modified to form a tube that acts as a siphon to feed on liquid nutrients. Some groups have the mouthparts completely reduced or absent, and do not feed at all as adults.

The majority of adult Lepidoptera have large wings that are coupled in some way to increase flight efficiency. In some groups, the front and hind wings are amplexiform, or overlap, to achieve synchrony. Other groups have a jugum, a lobe that projects from the rear margin of the forewing at the base, which interlocks with the hind wing. Most groups have a frenulum, a spine or group of stout hairs that projects from the front margin of the hind wing at the base. The frenulum connects with a row of hairs along the rear margin of the forewing. In a few species, females are brachypterous ("brachy" = "shortened"); examples include some species of Geometridae and Erebidae. Wing venation patterns are important for family-level identification in this order. You may also be glad to know that colour patterns have also been well-documented for most groups, and you will largely be relying on wing shape and colour to help you identify families in this lab.

There are about 150,000 species of Lepidoptera documented worldwide, with about 11,000 species known from North America. Some groups, especially the day-flying butterflies, are well-known, while many of the smaller, more cryptic and nightflying moths are less well-known – unless they are significant pests of agricultural or forestry crops. Larvae are mostly herbivorous, but at least one species from Hawaii, a *Eupithecia* sp., is a known predator of other insects as a larva, and another is a predator of snails. Adults, as previously noted, are mostly fluid-feeders, subsisting on nectar and/or minerals from mud, dung, and carrion. One lineage of the Noctuidae family contains known hematophagous members.

Lepidoptera have a similar system of sex determination as humans but, in the butterflies and moths, females are heterogametic (WZ), and males are homogametic (ZZ). Some species, in families, like the Psychidae, are commonly or entirely parthenogenic. Sexual reproductive behaviours are often complex, and commonly rely on chemical communication. The entire order is holometabolous, as are 80% of insects. Eggs are laid singly or in batches, sometimes on a host plant but often not. Many groups overwinter, in temperate climates, as eggs, with about 80% of the embryonic development already completed.

Lepidoptera larvae, or caterpillars, closely resemble larvae of the Hymenoptera suborder Symphyta, or sawflies. You should be able to tell Lepidoptera larvae apart from Hymenoptera larvae. Lepidoptera larvae have three pairs of jointed thoracic legs and, normally, five pairs of prolegs. Prolegs are extensions of the abdominal wall that act as support for the elongate body of the caterpillar. They are not jointed appendages. Each proleg in Lepidoptera has a row or circle of tiny hooks on the distal end, which the caterpillar can use to grip the substrate. Larvae of the family Geometridae have only two pairs of prolegs at the very end of the abdomen. When these larvae move they bring the back prolegs up to just behind the jointed thoracic legs, causing them to move like “inchworms” or “loopers”.

Larval Lepidoptera, despite their herbivorous habits, are often spectacularly well-defended from predators. Some sequester toxins from their food plants and use aposematic colouration to advertise their unpalatable or toxic nature. Predictably, there are also mimics of these unpalatable larvae. Other larvae mimic other distasteful or dangerous things such as bird droppings or even snakes. Some larvae also have urticating hairs or spines that can cause severe reactions in some people and domestic animals. A number of larvae produce repellent aromatic compounds on structures called osmeteria that can be extruded from between certain sclerites. Finally, the majority of Lepidoptera larvae are extremely cryptic, essentially the same colour as their host plants, and often exhibiting deceptive behaviours e.g. mimicking small twigs (Geometridae larvae are particularly adept at this!).

Most pupae are obtect, in the form of a chrysalis. In some groups, the last larval instar spins a protective cocoon before moulting to the pupal stage; in others, the pupa is buried in soil or attached to a leaf or stem of the host plant or another object.

The taxonomy and systematics of Lepidoptera are difficult, and many interpretations exist. In general, you will encounter two main subgroups, which are likely not monophyletic. The Monotrysia have the two genital openings combined; the only family you might notice around Prince George is the Hepialidae, or ghost moths. Hepialidae are also the only jugate moths you are likely to encounter. In the Ditrysia, the genital openings are separate; this group includes all of the families we will cover in the lab.

Lepidoptera Identification Aids

Identification of Lepidoptera adults is largely based on wing venation patterns, which can be difficult to see in insects that have their wings covered in scales! Identification to species often requires dissection of genitalia, a skill I am not going to attempt to teach. You may have noticed that no key is given in your text, either. Lepidoptera is, however, one of the few orders in which photographic comparison strategies work reasonably well for identification. Pay very close attention to details, though, and be sure to read descriptions, and look at distributions. Keep in mind that there are many families in this order that we do not cover in the lab, especially among the micro-Lepidoptera.

The photos in your text, and the online sources provided here, should help you identify most of the specimens presented in the lab. You may need to extend your search in order to identify Lepidoptera families in your collections (especially small, brown moths!!). Below are some links to some sites that are helpful in narrowing down your identification. I am always happy to help you figure out what you have, too!

General:

E-Fauna: https://ibis.geog.ubc.ca/biodiversity/efauna/

iNaturalist: https://inaturalist.ca/

BugGuide: https://bugguide.net/node/view/15740

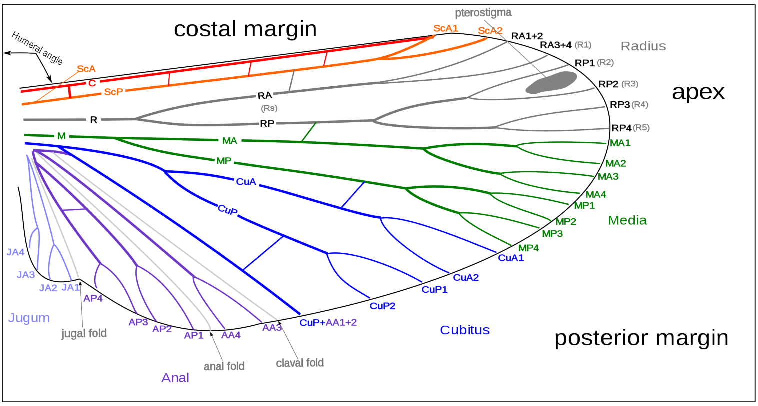
Lepidoptera-specific:

Moth Photographers' Group: https://mothphotographersgroup.msstate.edu/

Pacific Northwest Moths: http://pnwmoths.biol.wwu.edu/

Lepidoptera of the Pacific Northwest: Caterpillars and Adults: https://www.fs.fed.us/foresthealth/technology/pdfs/FHTET_03_11.pdf

I also include here a diagram of the standard Comstock-Needham system of wing vein nomenclature. If you wish to use a dichotomous key to identify any of the specimens in your collection, please let me know. There are a number of tips and tricks that I can share that will help you see various wing veins on a properly spread Lepidoptera without destroying the wings.



Bugboy52.40, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

65. Lepidoptera Families I

Tineidae

The first family you should be aware of is the Tineidae, or clothes moths. The larvae are tiny and rather drab (cryptic). They specialize in feeding on dead hairs of various animals. This has made them pests of natural wool and fur garments, and important museum pests in vertebrate collections. We do not have a definitive specimen in the collection.

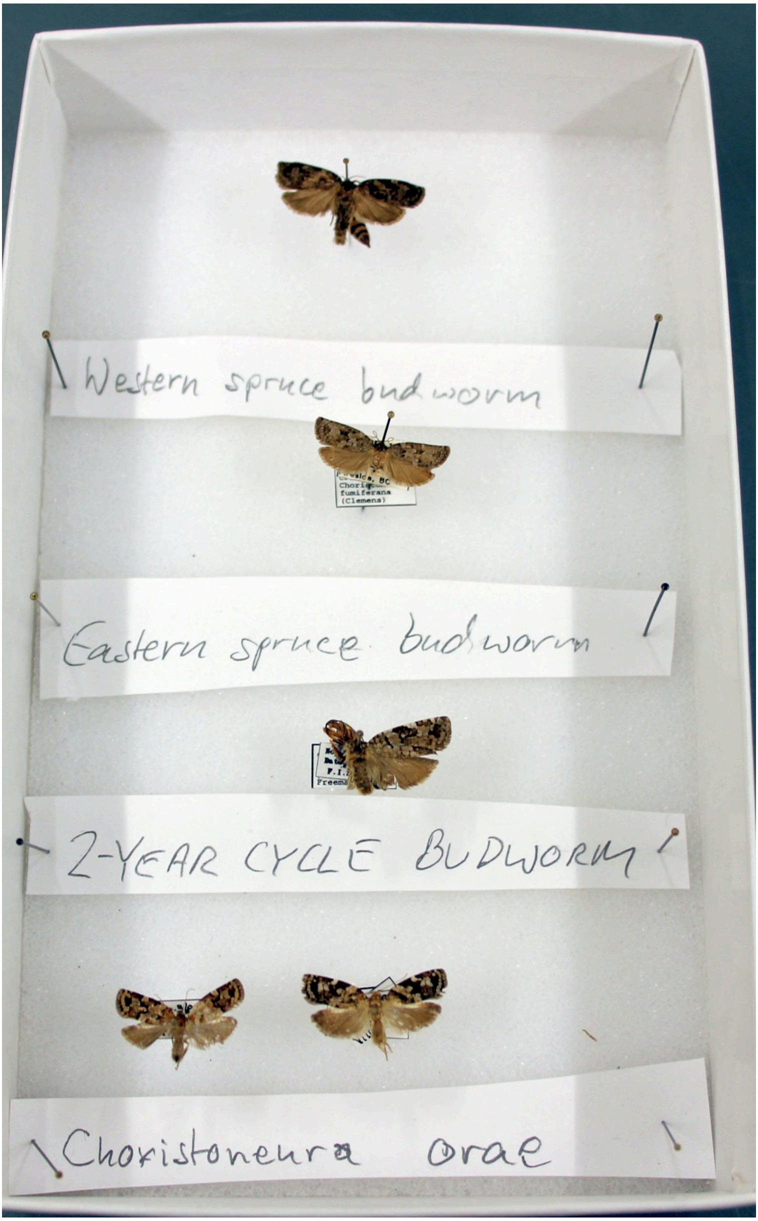
Tineola bisselliella: Clemson University – USDA Cooperative Extension Slide Series, Bugwood.org, CC BY 3.0 US

Sesiidae

Sesiidae, the clearwing moths, Have the win scales confined to only a few places on each wing. Normally, the scales are concentrated around the edges of the forewings, but may also be found along major wing veins. The adults are mostly Batesian mimics of stinging Hymenoptera, and can be tricky to tell apart from wasps at first glance. The larvae are mostly wood borers. We sometimes receive specimens of *Synanthedon novaroensis*, the Douglas-fir pitch moth. The larvae of this species can be found in large pitch masses on the trunks of various conifer hosts. They can be significant pests of lodgepole pine in BC. Further south, several species bore in the trunks of fruit tree species.

Tortricidae

Many members of Tortricidae are also serious agricultural, horticultural, and forest pests. They have various common names, often based on the host's symptoms: e.g. leaf rollers, budworms, etc. Both larval and adult members of individual species can be highly variable, making it difficult to determine species without in-depth diagnostic work and information on the host, the geographic location, and the habits. Most larvae in the family build some sort of feeding shelter, either rolling a leaf up with silk, or webbing together multiple leaves at a branch tip. As adults, the best characteristic to look for is the bell-shaped outline of the folded wings at rest. Spruce budworms, *Choristoneura* species, are serious defoliators of various coniferous trees in North America.



Pterophoridae

Pterophoridae, or plume moths, resemble crane flies. Both the front and hind wings of moths in this family are subdivided into "plumes", which are furled together and held perpendicular to the body at rest. The furled wings typically give the adult a characteristic "T" shape.

Pyralidae

Pyralidae includes the snout and grass moths. This family also includes a number of economically important pest species: see the Wikipedia list at https://en.wikipedia.org/wiki/Pyralidae. Many of the adults resemble adults of the Tortricidae (little, brown moths, or LBMs!), but notice the difference in the outline of the folded wings at rest. Tortricidae have that characteristic bell-shaped outline, while Pyralidae have a triangular, straight-sided outline. They often also have the mouthparts extended to the front of the head and heavily scaled, resembling a "snout". A caution, however: Crambidae, which we do not cover in the lab, is also common, and also has a "snout" and a triangular wing outline. Crambidae has been separated from Pyralidae relatively recently. The photo below is of *Dioryctria cambiicola*, the western pine moth. Larvae form small pitch masses on lodgepole pine, especially at the edges of stem rust cankers.

Hesperiidae

Hesperiidae, the skippers, are a day-flying group. The adults are relatively small, stout bodied Lepidoptera that fly quite fast. Many have orange patterns on the wings, and all have distally enlarged, hooked antennae.

Papilionidae

Papilionidae includes the swallowtails and parnassians. Many members of this family are large, flashy brightly coloured as adult butterflies. The larvae are also large and heavy-bodied. Both adults and larvae may be distasteful or mimic other species that are distasteful. Papilionidae are popular amongst collectors because of their relatively large size and bright wing colours.

Pieridae

Pieridae include the whites, sulphurs, and orangetips, named for the colours of their wings (as you might have guessed!). A number of species are important pests. Examples include the cabbage white, *Pieris rapae*, the larvae of which feed on all members of the cabbage family, and the white pine butterfly, *Neophasia menapia*, which feed on foliage of coniferous trees as larvae.

Lycaenidae

Lycaenidae are also known as the gossamer-winged butterflies, and include the blues, hairstreaks, coppers, and metalmarks. Some taxonomists separate the metalmarks into a separate family, the Riodinidae. Lycaenidae larvae are often associated with ants, communicating with the ants via substrate drumming (sound) and semiochemicals. They may overwinter in ant nests. Colour patterns on the undersides of the wings are often helpful to distinguish species, and I have "enhanced" these photos to show these features.

66. Lepidoptera Families II

Nymphalidae

Nymphalidae is the largest family of butterflies, with over 6000 species described. They are also called the brush-footed butterflies, and the family includes many of the best-known butterfly species. Many are very brightly coloured (the monarch butterfly, *Danaus plexippus*, is in this family) and their larval and adult habits vary widely. The front legs on many of these butterflies are reduced and modified into “brushes”, so only two pairs of jointed legs are readily apparent. Again, it is often necessary to look at the patterns on both the tops and bottoms of wings to determine an identification. I have included photos of several members of the family (top and bottom views are paired) and one typical larva.

Geometridae

Geometridae is a large moth family, commonly called loopers or inchworms. The larvae do not have the usual five or six pairs of prolegs along the body. Instead, they have only two pairs at the end of the abdomen. As a result, they move in a characteristic "looping" or "inching" way. Adults usually have triangular forewings and fan-shaped hindwings, and there are often wavy lines on the wings parallel to the edges. There is considerable variation in wing shape and pattern in this family, however, so double-check your identifications carefully. There are several significant pests of agriculture and forestry in this family, including the winter moth (*Operophtera brumata*; a species introduced to BC that defoliates fruit trees and Garry oak), and the western hemlock looper (*Lambdina fiscellaria lugubrosa*, a native defoliator of many conifers in hemlock-dominated ecosystems).

Lasiocampidae

Lasiocampidae, the tent caterpillars and lappet moths, are common defoliators across northern temperate forests. Adults are usually brown moths with stout, hairy bodies. They do not feed. Larvae are often colourful, longitudinally striped in various patterns, and hairy. The larvae are gregarious, and some species build communal webs ("tents") in host trees. Prince George experiences periodic outbreaks of forest tent caterpillar, *Malacosoma disstria*, a gregarious species that does not construct a tent. The larvae are distinctively blue, with white, keyhole-shaped markings along the dorsal midline.

Bombycidae

We do not have a specimen of Bombycidae in the UNBC collection. This is, however, a family you should be aware of – it has had a substantial influence on human history! The best-known representative is *Bombyx mori*, the silkworm. It is originally from Asia, and has been entirely and widely domesticated for silk production. The larvae feed exclusively on mulberry leaves.

Lilly M real name Małgorzata Miłaszewska, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Bombyx_mori1.jpg: Zivya derivative work: Linksfuss, CC BY-

SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Saturniidae

Saturniidae larvae also produce massive quantities of silk for their cocoons, leading to the common name of giant silk moths. Several species are exploited for so-called "wild silk", but they have not been domesticated like *Bombyx mori*. Adult Saturniidae are large, showy moths. The larvae are correspondingly large, and a few species are used as protein-rich food in some cultures. The species pictured here, *Hyalophora columbia*, was found on our property in Prince George as larvae feeding on Canada buffaloberry.

Sphingidae

Sphingidae, the sphinx or hawk moths, is another family of mostly large, showy moths. Some larvae (hornworms) have a "horn" at the tip of the abdomen that can produce noxious chemicals to repel predators. A few species of Sphingidae have clear wings, with the scales restricted to the edges of the wings and the largest veins. The hummingbird clearwing, *Hemaris thysbe*, is relatively common in Prince George when and where lilacs are flowering. Be sure to compare the overall wing and body shapes between this family and the Saturniidae.

Erebidae

Erebidae is among the largest moth families, and includes the tussock moths, tiger moths, and underwings. There are many important agricultural and forestry pests in this family. The subfamily Lymantriinae, the tussock moths (e.g. Douglas-fir tussock moth, *Orgyia pseudotsugata*), have urticating hairs as larvae and many have brachypterous adult females. The larval hairs are incorporated into the cocoon, where the larva pupates. When the female emerges, she remains on the cocoon, broadcasting sex pheromone. Once mating is complete, she also deposits her eggs on the cocoon; thus, the hairs serve to protect multiple stages of the insect. Tiger moths are usually very brightly coloured as adults, but are best known by their larvae, like woolly bears, again covered in colourful urticating hairs. Underwings confine the bright colouration to the hind wings, while the front wings resemble tree bark. At rest during the day, the moth is almost invisible, but opens its wings and flashes bright colours if disturbed.

Several species in this family are also important introduced species in North America, including the satin moth (*Leucoma salicis*; white moth pictured below), which is common in north-central BC on aspen and other poplars, and the spongy moth, *Lymantria dispar*.

Noctuidae

Noctuidae, the owlet moths and cutworms, are probably the most common Lepidoptera included in student collections, along with Geometridae. There is considerable reclassification ongoing in this family, Erebidae, and several other taxa that we do not cover in this lab. Adult Noctuidae tend to have subtle wing colouration, mostly in shades of brown and grey, but there are exceptions. In comparison with other families you have seen in this lab, note the relatively stout body, narrow forewing, and plain hindwing. When identifying this family in your collection, you should recognize that there are several very similar groups, like the family Notodontidae, and double-check your identification carefully.


2 3 4 5 6

PART X

LAB 8: MECOPTEROID ORDERS II

67. Introduction

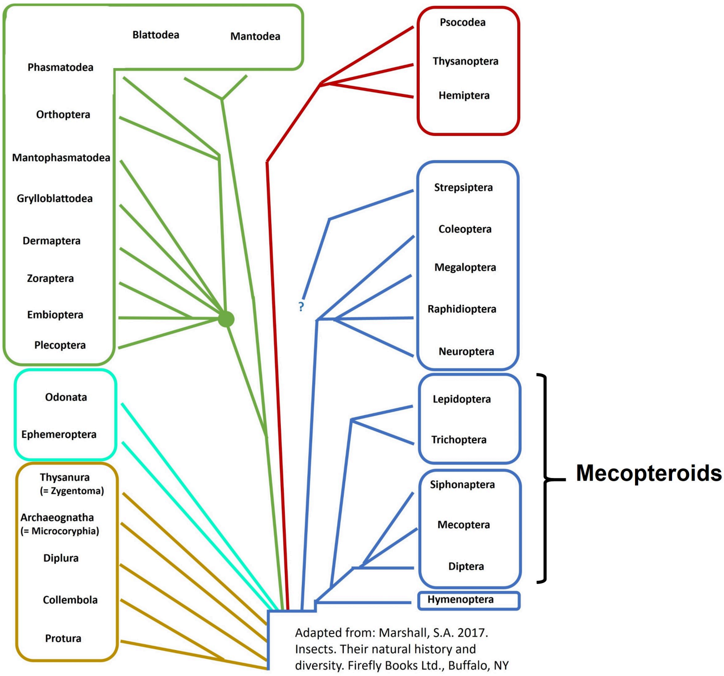
Introduction

This lab is the second covering the mecopteroid orders. As usual, your goal is to learn how to identify various common insects to order and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

The mecopteroids include five orders of insects:

- Trichoptera, the caddisflies;
- Lepidoptera, the butterflies and moths;
- Siphonaptera, the fleas;
- Mecoptera, the scorpionflies;
- and Diptera, the true flies.

We saw the first two orders in the previous lab, and the last three orders are covered in this lab. If your collection includes orders or families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know!


Blattodea
Mantodea
Phasmatodea
Orthoptera
Mantophasmatodea
Grylloblattodea
Dermaptera
Zoraptera
Embioptera
Plecoptera
Odonata
Ephemeroptera
Thysanura
(= Zygentoma)
Archaeognatha
(= Microcoryphia)
Diplura
Collembola
Protura
Psocodea
Thysanoptera
Hemiptera
Strepsiptera
?
Coleoptera
Megaloptera
Raphidioptera
Neuroptera
Lepidoptera
Trichoptera
Siphonaptera
Mecoptera
Diptera
Hymenoptera
Mecopteroids
Adapted from: Marshall, S.A. 2017.
Insects. Their natural history and
diversity. Firefly Books Ltd., Buffalo, NY

68. Siphonaptera

Siphonaptera

Siphonaptera ("siphon" = "tube"), or fleas, consists of about 2400 species worldwide, with approximately 325 species found in North America. Adults all have sucking mouthparts and are parasitic on vertebrates. They are also laterally flattened and wingless to assist with moving through the hair or feathers of their hosts. Their hematophagous habits, and ability to feed on several hosts in sequence, make them important vectors of diseases for humans and other hosts. The larvae of fleas are vermiform, and do not live on the host. Most are detritivores, and are often found in or near nests, dens, and bedding areas.

Adult fleas have a very distinctive body shape, and are relatively easy to identify to order.

69. Mecoptera

Mecoptera

Mecoptera ("meco" = "long"), the scorpionflies, is a small order, containing about 500 species. The larvae have compound eyes and are mostly saprophages, while adults can be saprophagous or predatory. Once again, these insects are easily recognizable, especially the males. The mouthparts of adults are elongated into a proboscis, giving the head a unique shape. The abdomen of the male has a bulb on the tip, and the entire abdomen is carried curled up above the back, like the sting of a scorpion. The bulb is not, however, capable of delivering venom. Instead, it produces a sex pheromone, to which the female is attracted. When she arrives, the male offers her some food. If she flies away, he is rejected; if she accepts him, she eats while they mate. The duration of mating depends on the size of the food offering.

The snow scorpionfly (*Boreus* sp.), lives in cold, high alpine habitats. A representation of *Boreus elegans*, a resident of high coastal mountains in BC, forms part of the logo of the Entomological Society of British Columbia, http://entsocbc.ca/.

Mecoptera male: Charles J. Sharp, CC BY-SA 4.0

<https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

Boreus brumalis: Ben Armstrong, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons

70. Diptera - Introduction

Diptera

Diptera, the (true) flies, is a huge order of insects, with plenty of undocumented diversity. Flies tend to be the dominant fauna in Arctic and sub-Arctic regions, both in terms of species richness, and in terms of abundance (e.g. think mosquitoes and black flies!). Many species are extremely important to humans. Diptera is divided into two suborders, Nematocera and Brachycera.

As members of a very large order, flies can be highly variable. One characteristic is common to all Diptera: they have a single pair of wings (or occasionally no wings at all) as adults, and never two pairs. The hind wings if Diptera are reduced and modified into small, club-like structures called halteres. Halteres are used as a balance organ to facilitate rapid, maneuverable flight. They can be tricky to see in some groups, but are readily apparent in other groups. Remember that male Strepsiptera also have halteres, but it is the front wings that are modified and reduced in Strepsiptera.

Some of the key features you will need to use to identify flies are the number of antennal segments; the presence/absence of a structure called the greater ampulla, the presence/absence of a row of bristles on a sclerite called the meron; and the relative size of the calypters. Rather than trying to define all of these features, I have illustrated them below. Please contact me with any questions!

1. Antennal segments

   a) 6 or more:

b) 5 or fewer:

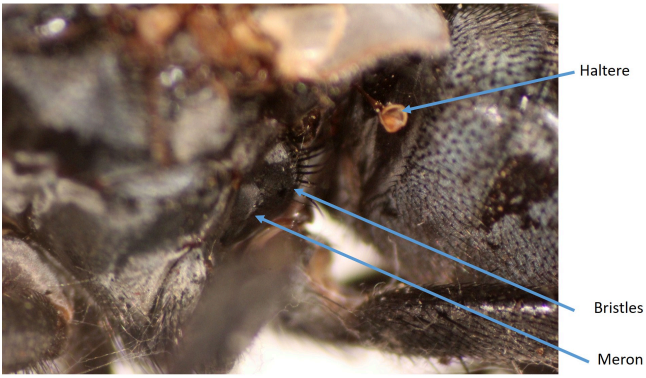
2. Greater ampulla present/absent

a) Present:

b) Absent:

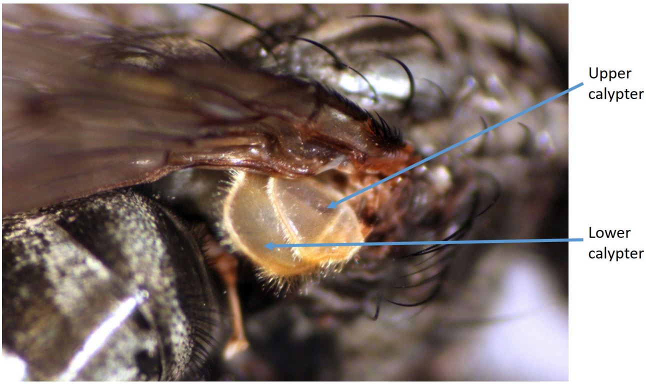
3. Meron with row of bristles

a) Yes, present:



b) No, absent:

4. Calypters (lower larger than upper, in this case):



71. Diptera - Nematocera

Nematocera

The suborder Nematocera ("nemato" = "thread", "cera" = "antenna") is an extremely important subgroup for humans. Many of the most common hematophages are in this suborder, and it includes many important vectors of human and animal diseases. The entire suborder is characterized by having antennae with five or more segments.

Tipulidae

The first family of Nematocera that we look at is Tipulidae, or crane flies. While many people describe them as "giant mosquitoes", they are **not** hematophagous. Most of the adults are quite fragile, and frequently lose legs while being collected or preserved. Larvae are herbivorous or detritivores. Some species have aquatic larvae that are sacvengers. Other larvae feed on plant roots, and can be considered pests of lawns, golf courses, and plant nurseries.

Adult tend to have elongate, obvious halteres, and a typical "gangly", long-legged appearance. There are a few related families that we do not cover in the lab, but Tipulidae is usually distinguishable by a V-shaped suture on the dorsum of the thorax.

Bibionidae

Bibionidae, the March flies, includes about 650-700 species. They are scavengers, and tend to occur in large swarms following synchronous emergence. Some species spend almost their entire adult lives copulating, leading to their other common name, “lovebugs”. They can be sexually dimorphic.

Sciaridae

Sciaridae are the dark-winged fungus gnats. As the common name suggests, they are scavengers. They are common nuisance insects in house plants, greenhouses and nurseries.

Cecidomyiidae

Cecidomyiidae, the gall midges, includes several economically important pest species. Feeding of the larvae on plant parts induces a physiological response in the plant, which produces a gall or swelling. The Douglas-fir cone gall midge, *Contarinia oregonensis*, can be quite destructive in tree seed orchards, where it induces a gall that fuses the seed to the cone scale, making it difficult to extract the seed for planting. These are very small flies, and there is no well-preserved representative in the UNBC collections.

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Chaoboridae

Chaoboridae, the phantom midges, are common in and near freshwater ecosystems. The larvae are pelagic and clear-bodied, except for two air sacs at the front and rear that help the larva maintain neutral buoyancy in water. Larvae are predatory, and use raptorial antennae to grab small prey such as mosquito larvae. The adults resemble mosquitoes, but lack the proboscis, even on females.

Piet Spaans, CC BY-SA 2.5 <https://creativecommons.org/licenses/by-sa/2.5>, via Wikimedia Commons

This image is created by user B. Schoenmakers at waarneming.nl, a source of nature observations in the

Netherlands., CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons

Culicidae

If you live almost anywhere in Canada, you should be familiar with Culicidae, the mosquitoes. Adults have piercing-sucking mouthparts, and many females are obligate or facultative blood-feeders. Vertebrate blood is needed as a protein source to enable females to produce well-provisioned eggs. Species that are facultative blood-feeders are mostly found in the Arctic, and can produce some eggs even without a blood meal. They produce more eggs, with more resources per egg, if they are blood-fed. Some species will feed on multiple hosts, and even on multiple host species. These mosquitoes are the species that are important vectors of various blood-borne pathogens, like malaria. Adult males feed mostly on nectar, and can be important pollinators in some areas.

Mosquitoes lay their eggs in stationary water. Larvae can develop in a surprisingly small amount of water: rain water puddles, evn hoof prints can be important breeding grounds. Some mosquitoes breed in specialized habitats, like water that accumulates in tree cavities. These species have also often adapted to use anthropogenic sources of pooled water, with abandoned tires being a favoured habitat. Larvae feed mostly on algae and detritus, but a few species are predatory.

Five genera are represented in northern British Columbia. *Anopheles* spp. feed in a characteristic manner, with their heads down towards the skin of the host, and the abdomen pointing upwards. Their larvae are also distinctive, having a very short siphon, the breathing tube off the tip of the abdomen where the spiracles are located, and resting horizontally at the surface of the water to breathe. *Culiseta* spp. are large mosquitoes active later in the summer, while *Culex* spp. tend to emerge very late into the fall. Several *Culex* spp. feed on birds as well as humans, and are likely sources for potential

West Nile virus transmission. *Aedes* spp. (now divided into two genera, *Aedes* and *Ochlerotatus*) are the main species that we notice around Prince George in late May and June. There are quite a few species, some of which breed in temporary snow-melt pools and emerge as adults almost as soon as the snow is thawed. Others in this genus are called floodwater mosquitoes; these lay their eggs in the mud on the margins of rivers and ponds. They hatch when the freshet starts and the water levels rise, then quickly complete development. The last genus, *Mansonia* (=*Coquillettidia)*, is represented here by the cattail mosquito. The larval siphon is modified into a saw-like structure that is used to tap into the air pockets in cattail roots. The larva then remains at the bottom of the pond, feeding on algae and detritus and breathing via the cattail roots. It has no need to expose itself to predation by surfacing periodically to breathe.

The larva pictured below with an extra-long siphon is a *Culex territans* specimen; adults feed on frogs and other amphibians.

Simuliidae

Simuliidae are the black flies or buffalo gnats. Members of this family are also hematophagous as adults and are important disease vectors. They use a technique known as pool feeding. Adults use their saw-like mouthparts to tear a small hole in the vertabrate host's skin and access the capillary blood flow underneath. As the blood pools on the surface of the wound they suck it up. They also have anticoagulants and anaesthetics in their saliva that keep the blood from clotting and the host from swatting. You may notice that you continue to bleed from black fly bites even thought the insect has already left: this is why. Ins some areas, e.g. the Athabasca River valley and near the Abitibi River, adults can occur in sufficient numbers to kill livestock. Their bites can also have a serious impact on the physical and mental health of humans. For a rather light-hearted look at some of the effects black flies had on early settlers in what is now northern Ontario, see the National Film Board short, "Blackfly", at https://www.nfb.ca/film/blackfly/.

Black fly larvae are sessile filter-feeders in running water, and their antennae are modifed as collectors. Black fly populations tend to be highest where there is running water. Pupae are shown in the last photo, attached to some underwater vegetation. In the adult photos, note the strongly humped prothorax (leading to the common name "buffalo gnats"), and the wing vein pattern. These are quite distinctive.

Ceratopogonidae

Ceratopogonidae is yet another family of hematophagous insects. They have several common names, including no-see-ums, sand flies, and biting midges. They are very tiny, and regular window screening is usually insufficient to exclude them from buildings. Like Simuliidae, the adults are pool feeders. Larvae are usually aquatic, but some can even develop in moist or waterlogged soil. Below is one the I recovered from a pitfall trap collection at the Aleza Lake Research Forest. It was likely an incidental capture, having been inadvertently transferred from my hand, which it was attempting to feed on, to the collecting vial!

Chironomidae

Chironomidae is a large, diverse family of non-biting midges. They form an important link in aquatic food webs, feeding on detritus and algae and providing food for a wide range of vertebrates and invertebrates. They often emerge synchronously in a very short period of time, resulting in truly impressive “swarms”. Adults look very much like adult mosquitoes, but lack a proboscis. The pronotum also has a distinctive feature, a transverse groove or suture across the rear part, just behind the wings (shown below).

Larvae are aquatic, and can be important bioindicators of water quality. It is essential to identify them to the genus or species level though, and that can be extraordinarily difficult. Some species are indicators of high oxygen content, while others thrive in very low-oxygen water. Some, often called “bloodworms”, even have hemoglobin in the hemolymph, to help bind oxygen in near-anaerobic conditions. These species tend to dominate at the bottoms of lakes, or in marshes.

72. Diptera - Brachycera

Brachycera

The suborder Brachycera ("brachy" = "short", "cera" = "antenna") is the larger of the two suborders in Diptera. The entire suborder is characterized by having antennae with fewer than five segments. The suborder is extremely diverse, with some fascinating and novel life cycles and reproductive strategies. Some exhibit paedogenesis, and some are larviparous or even pupiparous. Many families show a high degree of specialization, especially the parasitic groups, and many are important for human and domestic animal health, and as bioloigcal control agents.

Tabanidae

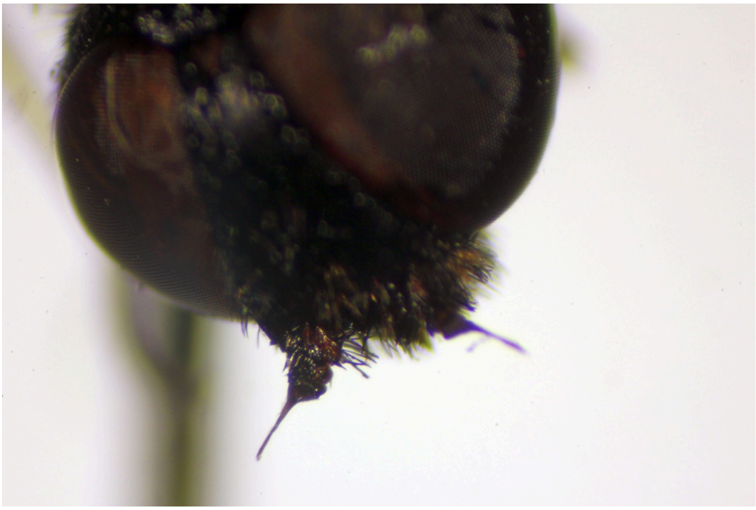
If you have done any outdoor work or recreation in northern Canada during the summers, you will recognize this family! Tabanidae includes the horse flies and deer flies. The adults are very strong fliers with haustellate mouthparts and large, often colourful eyes. They can be extremely persistent in their pursuit of a potential blood meal. Much like black flies and no-see-ums, they are pool feeders, and leave a large painful wound. When they are plentiful, they can cause severe blood loss for livestock or unprotected humans. They can also vector diseases, and are important especially in the tropics. The larvae are aquatic or semi-aquatic.

Asilidae

Asilidae, or robber flies, are sturdy, voracious predators. There are about 2000+ species worldwide, and about 850 in North America. Some species are quite large, and they often tend to be fuzzy. One of the distinguishing features of the family is a concave indentation on the top of the head, between the compound eyes; the other is a tuft of setae on the front of the face, called a mystax. Adults sometimes establish feeding or mating territories, and are commonly found on a raised perch somewhere fairly open. When disturbed, they will generally return to the same perch eventually.

Bombyliidae

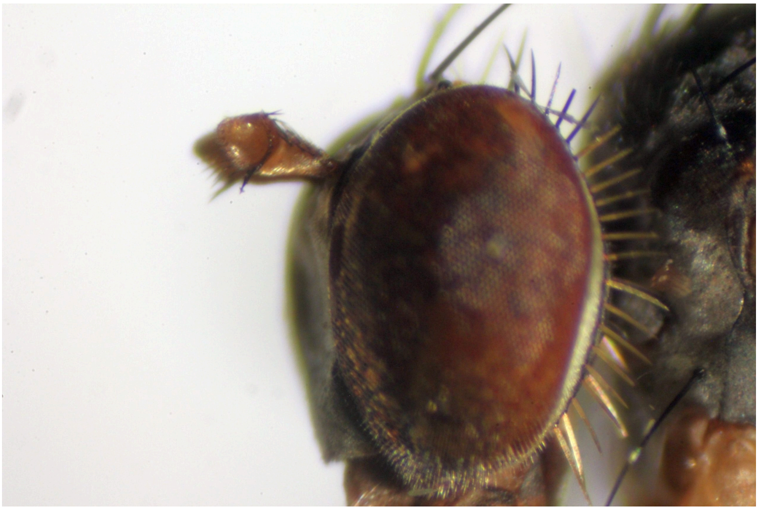
Bombyliidae, the bee flies, are plump, hair bee-mimics. Their wings are often patterned with dark markings and held out to the sides even when at rest. Some have a long proboscis that is non-retractile. Larvae are found in the soil, and are predatory or parasitic on digger wasps and bees.



Dolichopodidae

Dolichopodidae, the long-legged flies, have (as you might expect) very long legs in proportion to their body size. Adults are predatory, andthe larvae may be predators or scavengers.

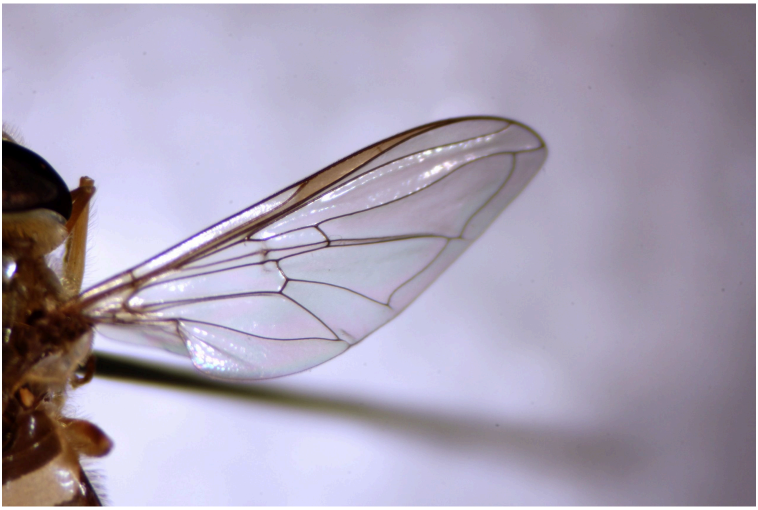
Mating often involves complex dance rituals, territories, and mate guarding using visual cues.



Syrphidae

Syrphidae are the flower flies, drone flies, or hover flies. Most adults are Batesian mimics of stnging Hymenoptera, and many are really good mimics. Adults are usually found hovering at flowers or in other locations, and people often mistake them for wasps. Many of the larvae are active predators of other insects. A few, like *Eristalis tenax*, have larvae that live in very low oxygen water. Known as rat-tailed maggots, the siphon is often as long as, or even longer than, the larval body.

Distinguishing these from Hymenoptera is important. Hymenoptera have two pairs of wings (although they are often coupled); Syrphidae, being members of the order Diptera, have only a single pair. Adults also have aristate antennae, along with larger eyes and a differently-shaped head than Hymenoptera. The distinctive family-level identifying feature is called a spurious vein. It looks a lot like an extra vein superimposed on the "normal" Diptera wing venation pattern (shown in the wing photo below).



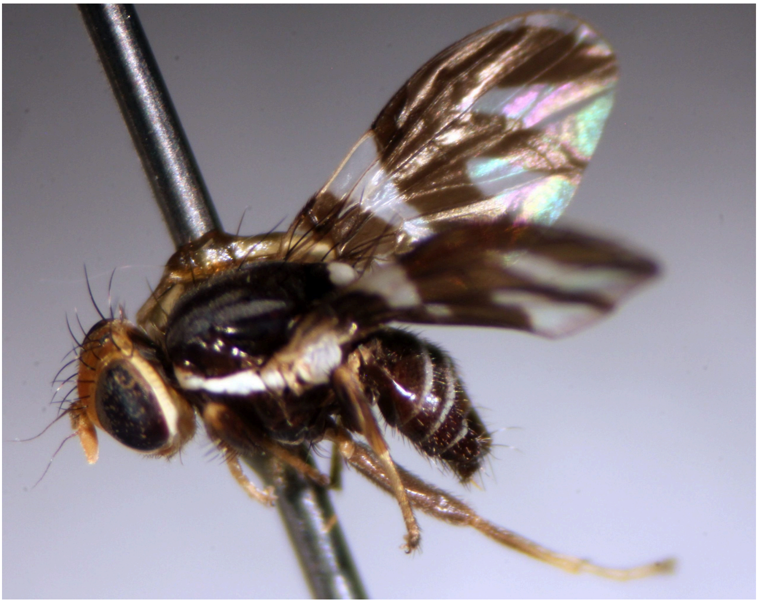
73. Diptera - Brachycera - Muscomorpha

All of the remaining Diptera families that we cover are members of the Infraorder Muscomorpha, or Cyclorrhapha. They all have an inverted horseshoe-shaped suture on the front of the face. This suture allows the expansion of the ptilinum, a structure that helps to break open the puparium when the adult fly emerges. All members also have aristate antennae.

Tephritidae

There are numerous economically important species in the Tephritidae, or fruit flies. Their larvae commonly mine in fruits: e.g. the apple maggot fly, *Rhagoletis pomonella*, and the cherry fruit fly, *Rhagoletis cerasi*. During oviposition, adult females frequently mark fruits with a pheromone so that other females do not oviposit into the same fruit. Some species have wing markings that mimic jumping spiders.

Tephritidae do not have a greater ampulla. Family identification will require you to look at the details of wing venation.



Drosophilidae

Drosophilidae are the small fruit flies, and this family includes *Drosophila* (=*Sophophora*) *melanogaster*, of genetic research fame. They are a distinct and distinguishable family from Tephritidae, but you will need some practice and a careful eye to separate the two families reliably. Also included in this family is an increasingly economically important species introduced to BC, *Drosophila suzukii*, the spotted wing drosophila. The species lays its eggs in various cultivated and wild small fruits, making them mushy and unappetizing to humans. The larvae even survive composting.

Muscidae

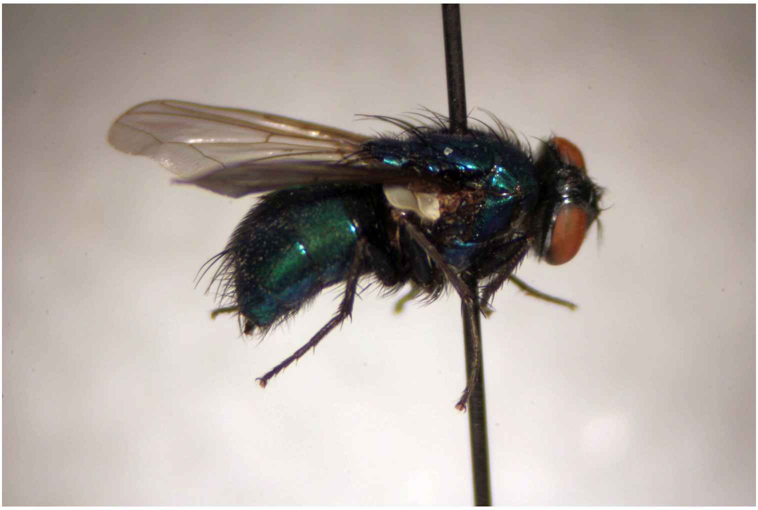
Muscidae are the muscid flies (pronounced musk-id), house flies, or stable flies. The best-known species is *Musca domestica*, the common house fly. Many members of this family are of ecological importance as decomposers, while others have medical and veterinary importance. The family also includes the tsetse, a vector of sleeping sickness (a form of trypanosomiasis).

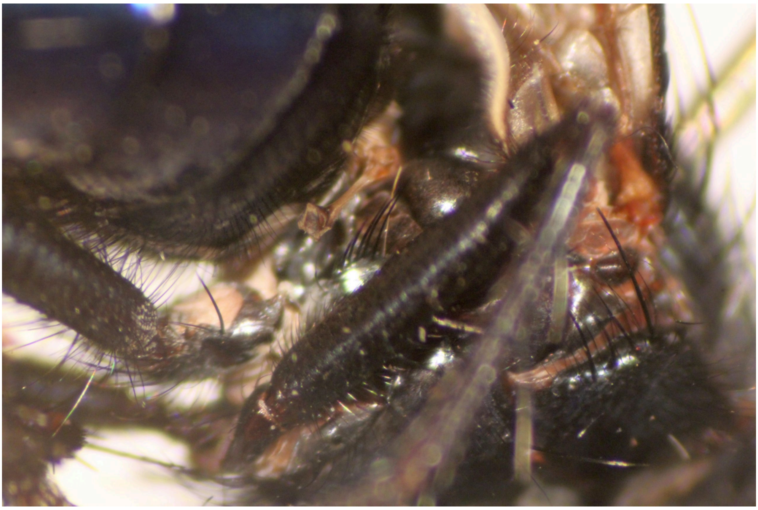
Adults have a greater ampulla, but lack a row of bristles on the meron. The arista of the antenna is plumose.

Calliphoridae

Calliphoridae are the blow flies. Almost all have metallic colouration, especially on the abdomen, as adults, and many are called "bottles": *e.g.* blue bottle flies, or green bottle flies. Most larvae feed on carrion or dung, but a few species have parasitic larvae. *Protocalliphora* spp. are important blood-feeders on hatchling birds in their nests. *Cochliomyia hominivorax*, the New World screwworm fly, is another economically-important fly in this family. Other members of this family are important in maggot therapy, and as forensic indicator species.

Note that adults in this family have both a greater ampulla and a row of bristles on the meron.





Sarcophagidae

Sarcophagidae are the flesh flies. They occupy a wide range of habitats, including flesh (usually decomposing), dung, wasp nests, and pitcher plants. Some species have larvae that are parasitoids of other insects. *Sarcophaga aldrichi* is a major parasitoid of forest tent caterpillar larvae. It has also earned the name “friendly fly”, because of its habit of sitting on vertical objects, including humans.

Most adult Sarcophagidae are striped grey and black flies. Like the metallic Calliphoridae, they have both a greater ampulla and a row of bristles on the meron.

Tachinidae

Tachinidae, or tachinid flies, is among the largest families of Diptera, with about 8200 species worldwide and about 1300 in North America. They are important parasitoids of other insects, and species tend to have a limited host range . Adults tend to very bristly and robust flies. Like the previous two families, they have a greater ampulla and a row of bristles on the meron; the postscutellum also bulges outwards. To see the latter feature, look from the back of the fly towards the head, between the wing bases.

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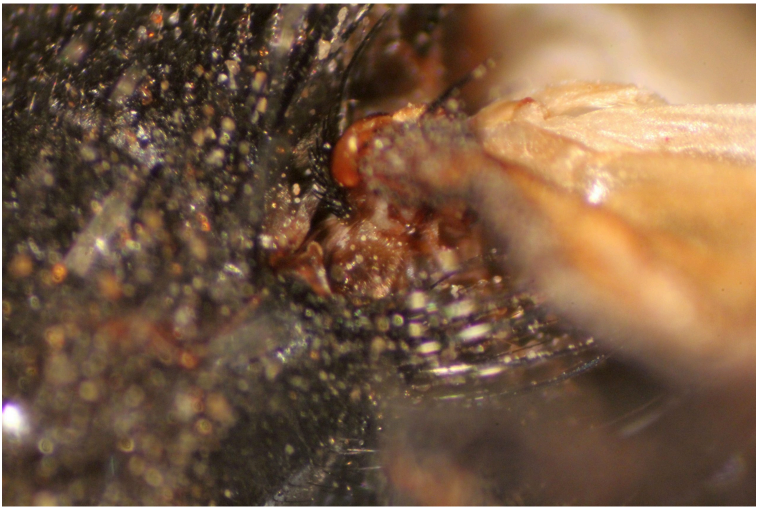
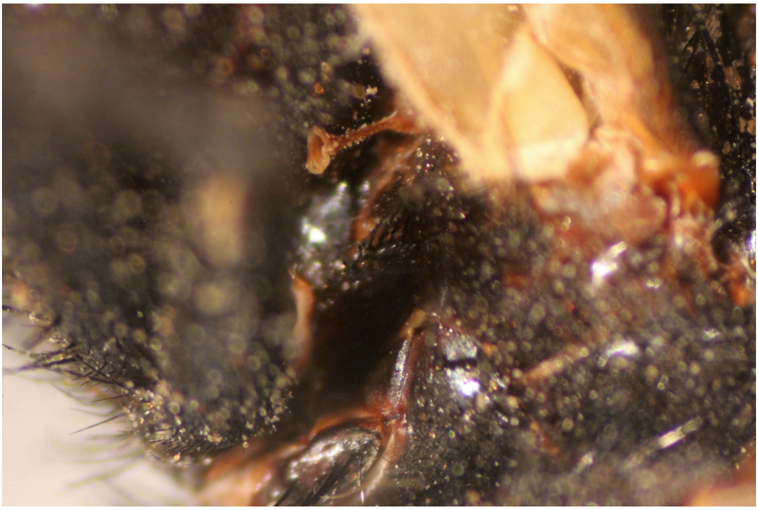




Oestridae

Oestridae are the bot flies and warble flies. Larvae are subcutaneous or endoparasites on various mammals. Small rodents with large bulges underneath their skins are often found to be carrying one or more of the large maggots. Oestridae are also important parasites of various herbivores including horses, sheep, cattle, and caribou. In tropical regions of Central and South America, there is an Oestridae that parasitizes mammals including humans. The female human bot fly, *Dermatobia hominis*, captures a blood-feeding insect, usually a mosquito, and lays an egg on its ventral surface. When she releases the mosquito, it will continue with its habit of feeding on vertebrate blood. When the mosquito bites a mammal, the heat from the skin surface will cause the bot fly egg to hatch, and the larva quickly burrows under the skin. It leaves a hole for the spiracle to acquire respiratory gases, and feeds underneath the skin. Myiasis (infestation by fly larvae) of incidental hosts is common in this family, so domestic animals like cats and dogs can become infested.

Adult bot flies are stout, hairy flies that resemble bees. Their mouthparts are highly reduced.

gailhampshire from Cradley, Malvern, U.K, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons

Hippoboscidae

Hippoboscidae are the louse flies. The entire family consists of ectoparasites of birds and mammals. Many species are secondarily wingless. Their bites are quite painful. Most of the larval development occurs inside the adult female's body and, when she finally larviposits, the larva pupates almost immediately. Occasionally these are added to the collection, either by researchers working on birds, or from birds freshly-killed in window-strikes. They have a peculiar, rapid, jittery movement.

Adults are dorsoventrally flattened, with a very tough exoskeleton to protect them from host grooming activities. The overall body shape can be quite variable depending on the species.

PART XI

LAB 9: HYMENOPTERA

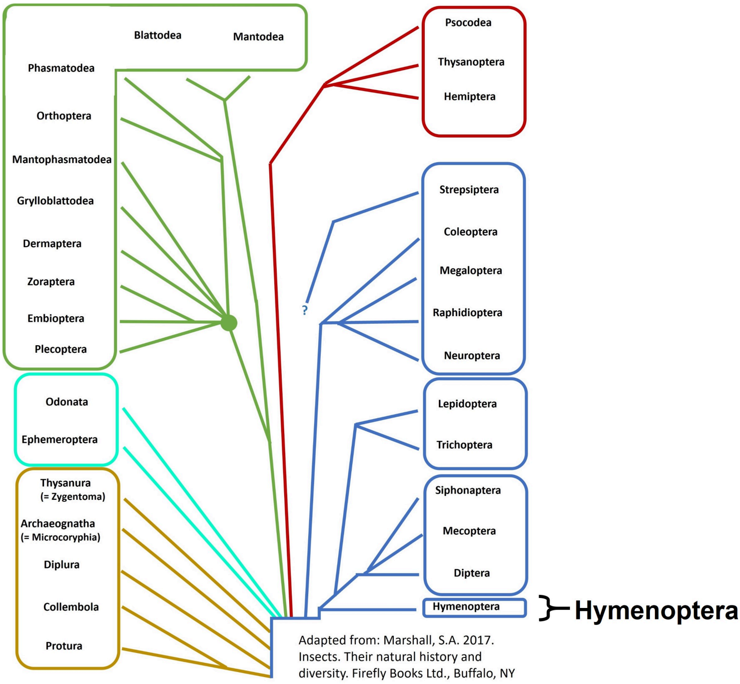
74. Introduction

Introduction

This lab covers only a single order, Hymenoptera. Your goal is to learn how to identify various Hymenoptera to order, superfamily, and/or family level using the keys in your text, online resources, other students, and me (when in doubt, ask an entomologist). The lab should take you approximately three hours to complete. A short quiz will be available when you have finished the lab, so that you can practice your identification skills.

Hymenoptera is an amazingly diverse order, with many species yet undocumented especially in the “micro-Hymenoptera” category. Considerable taxonomic revisions are both underway and necessary. If your collection includes orders or families not covered in the lab, they still need to be identified to family. If you need help with that, please let me know. As always, if you are having difficulty seeing what the key asks for, you aren’t sure what a photo shows, or you can’t quite match up the photos available with what the keys in the back of your text ask you to assess – please ask!

There are two distinct suborders, Symphyta and Apocrita, with the greatest diversity occurring in the Apocrita.


Blattodea
Mantodea
Phasmatodea
Orthoptera
Mantophasmatodea
Grylloblattodea
Dermaptera
Zoraptera
Embioptera
Plecoptera
Odonata
Ephemeroptera
Thysanura
(= Zygentoma)
Archaeognatha
(= Microcoryphia)
Diplura
Collembola
Protura
Psocodea
Thysanoptera
Hemiptera
Strepsiptera
Coleoptera
Megaloptera
Raphidioptera
Neuroptera
?
Lepidoptera
Trichoptera
Siphonaptera
Mecoptera
Diptera
Hymenoptera
Hymenoptera
Adapted from: Marshall, S.A. 2017.
Insects. Their natural history and
diversity. Firefly Books Ltd., Buffalo, NY

75. Some Key Characteristics

Some Key Characteristics

This chapter is intended to be a guide to some of the main features that you will need to see on Hymenoptera to determine families using the key in your text.

1 Abdomen broadly joined to thorax or petiolate

Broadly joined:

Petiolate:

OR:

2 Dorsal hump on petiole

With:

Without:

3 Pronotum triangular, squarish, or with a rounded lobe

Triangular:

Squarish:

Rounded lobe:

4 Number of m-cu crossveins

Two:

One:

5 Jugal lobe on hindwing

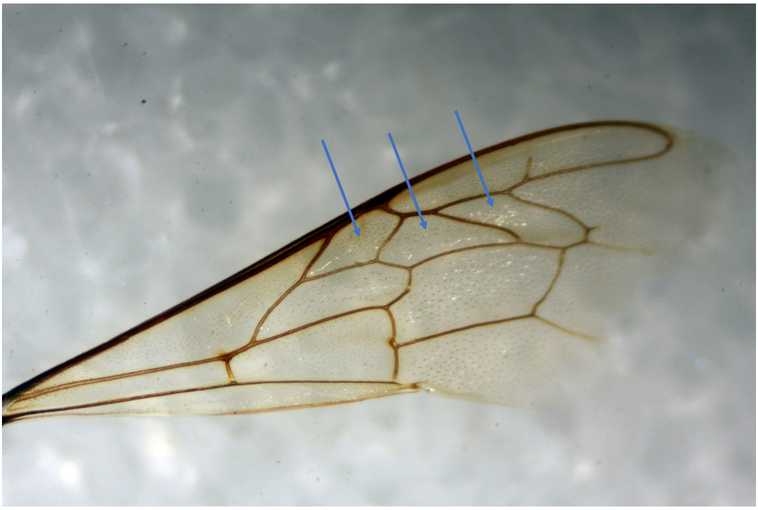
Long:

Short:

6 Submarginal cells on front wing

Two:

Three:



76. Symphyta

Symphyta

Symphyta includes the sawflies and wood wasps. The members of this suborder lack a petiole, or narrow “waist” between the thorax and the abdomen. The larvae are all phytophagous. Larvae of the various sawfly families are eruciform (caterpillar-shaped) and feed on foliage. It is important that you learn to tell these apart from Lepidoptera larvae. Hymenoptera larvae have prolegs on every abdominal segment, starting right behind the thoracic legs. They have six to seven pairs of prolegs, compared to the five or two seen in Lepidoptera larvae. The prolegs also lack crochets. Larvae of the wood wasps, or horntails, are found boring in wood, and are rather more grub shaped.

Diprionidae

Diprionidae are the conifer sawflies. Their larvae can be serious defoliators of various coniferous trees in the Northern Hemisphere. Antennae of adults are serrated in females, and pectinate in males. A female is shown here.

Tenthredinidae

Tenthredinidae, or common sawflies, is the largest group of sawflies, with over 7500 species worldwide. Adult females generally use their ovipositors to cut small slits in leaves or twigs. Eggs are then deposited in the slits, and the larvae defoliate the host plants. Both oviposition and the subsequent feeding damage by larvae can cause substantial damage to host plants.

The larva shown here is an introduced species to North America that defoliates various *Ribes* spp.

Cimbicidae

Cimbicidae are the cimbicid sawflies. They are large, heavy-bodied insects. The larvae resemble large caterpillars, and mostly feed on deciduous trees and shrubs. Adults have clubbed or knobbed antennae. The elm sawfly, *Cimbex americanus*, is occasionally found in the Prince George area. Larvae can be found after a windstorm near parts of town with elms, and can be green or even red to orange, with a black dorsal stripe. Adults are sometimes mistaken for giant hornets, and reported as exotic species.

Siricidae

The last family of Symphyta that we will cover is Siricidae, the horntails or wood wasps. Again, these are fairly large, robust insects, and are sometimes mistaken for giant hornets. They oviposit in wood, often in trees that have been killed or damaged by fire. Wildfire crews often encounter them poking their ovipositors into crevices in the bark of burned stumps. Adults have a pronounced "horn" on the tip of the abdomen, above the ovipositor and present in both males and females. Larvae bore in wood, and some species are severe pests of timber and wood in service. They are also easily moved around, so exotic species are always a concern.

77. Apocrita I

Apocrita

The remainder of the groups in Hymenoptera are in the suborder Apocrita. There is an enormous size range in this suborder, from completely microscopic to large and noticeable. the majority of groups in the Apocrita are predators or parasitoids, but there are some species that are highly coevolved with plants. There is also an incredible diversity of reproductive strategies in this group, including parasitoids, hyperparasitoids, inquilines, and various degrees of sociality.

The first abdominal segment of all Apocrita, called the propodeum, is fused with the thorax. This fused segment is separated from the rest of the abdomen by a narrow abdominal segment that forms the petiole. In some groups, the ovipositor is also modified into a stinger, complete with venom sacs and complex musculature, to defend the individual and/or its colony.

There are a number of superfamilies and, for some groups, I will recommend that you only learn the superfamilies. Taxonomy is very dynamic in the Apocrita, and even some families are difficult to identify with any certainty.

Braconidae

Braconidae is a family of parasitoid wasps, called braconid wasps. Wasps in the superfamily Ichneumonoidea (Braconidae + Ichneumonidae) are distinguished from other Hymenoptera by having two-segmented hind trochanters and antennae with >15 segments. Braconidae tend to be smaller than the next family, Ichneumonidae, but there are some exceptions. The best way to tell the two families apart is by using wing venation. Braconidae have a single m-cu crossvein in the forewing, while Ichneumonidae have two m-cu crossveins.

Ichneumonidae

Ichneumonidae is the second family in the superorder Ichneumonoidea, and are called ichneumon wasps. As you might expect, they tend to be quite similar to Braconidae, with two-segmented hind trochanters and antennae with >15 segments. Ichneumonidae are generally larger then Braconidae, but there are some exceptions. Again, the best way to tell the two families apart is by using wing venation. Ichneumonidae have two m-cu crossveins in the forewing, while Braconidae have a single m-cu crossvein. A shortcut, which is not 100% effective: look for the outline of a horse's head (a wing cell outlined by veins that includes a right-angle bend) in the venation pattern of the forewing. Almost all Ichneumonidae show this pattern. If the shape is lacking, or if the "horse is wearing a halter" (as in the wing pattern shown under Braconidae, where that same area of wing is divided into three cells by veins), check other characteristics to determine the family.

Superfamily Chalcidoidea

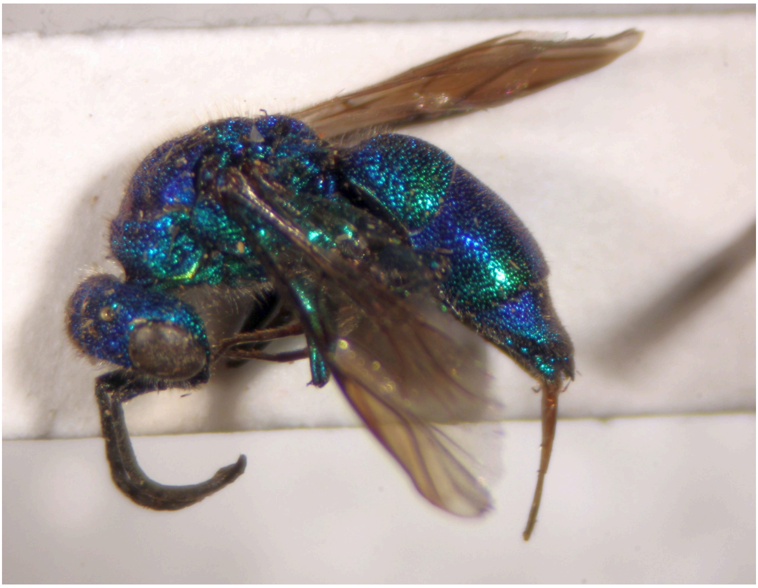
I am only asking you to be able to identify this group to superfamily. The superfamily Chalcidoidea (pronunciation = "Kal-sid-oy-dee-ah") includes some fascinating groups with diverse life cycles. However, almost all insects in this superfamily are very small and specialized, so you may not have any of this group in your collections. They also take some work to identify!

Many Chalcidoidea are parasitoids of other insects, hyperparasitoids of other parasitoids, or seed predators. Trichogrammatidae includes some very tiny wasps that oviposit inside other insects' eggs. Their larvae mature by feeding on that single egg, making them important biological control agents. There are several families that either cause galls (swellings) on plants, or that live inside galls caused by other insects as inquilines. Eurytomidae, Torymidae, and Chalcididae are some of these. Another important family in the Chalcidoidea is the Agaonidae, or fig wasps. They have a complex, coevolved relationship with fig trees. For more details, I encourage you to set aside time to watch PBS's "Queen of Trees", https://naturedocumentaries.org/2929/queen-trees-pbs-2006/.

The adult pictured here is *Megastigmus spermotrophus*, the Douglas-fir seed chalcid, a typical seed predator. Because each larva lives and grows inside a single seed, the only way of assessing damage prior to planting the seed is by X-raying the seeds.

Chrysididae

Chrysididae, the cuckoo wasps or emerald wasps, are in the superfamily Chrysidoidea. They are both metallic and punctate, and have a very hard exoskeleton. They are fairly small insects, so are rarely noticed. When seen up close, they are dramatic and beautiful. Many are also capable of folding or rolling up in a ball in self-defense, and you may see some of that flexibility retained in preserved specimens. The ventral surface of the abdomen may even be somewhat concave, providing a place to lock in the head and thorax. They are mostly ectoparasitic on bee or wasp larvae, or kleptoparasites in nests of other Hymenoptera.



Sphecidae

Sphecidae are the thread-waisted wasps or mud daubers. Most members of this family specialize on a particular prey type. Cicadas, crickets, caterpillars, spiders, and flies are all among the prey types used by these wasps. Generally, the prey is captured, paralyzed with venom, then deposited in a burrow. Eggs are then laid on the still-living prey; when the larvae hatch, they have a ready source of fresh food. A few species are kleptoparasitic, laying their eggs on the paralyzed prey of another wasp.

The petiole of adults is exceptionally long, giving the wasps the common name of thread-waisted wasps.

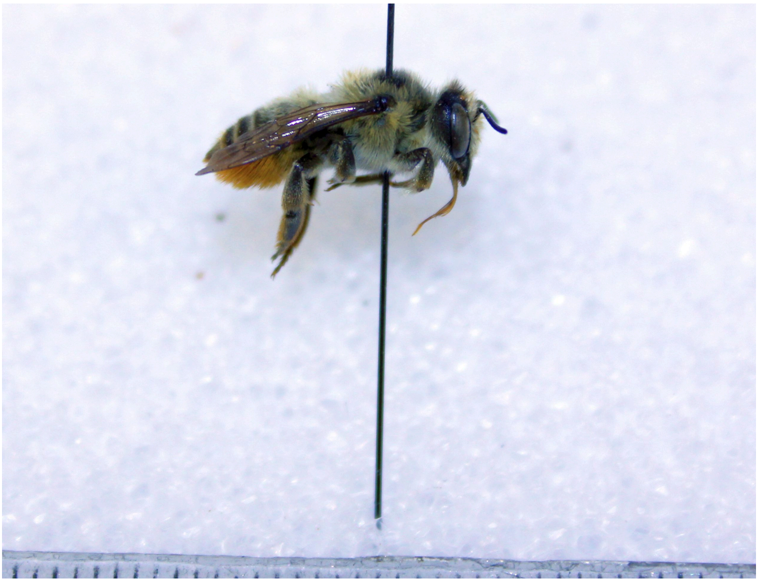
78. Apocrita II

Megachilidae

We will look at two families in the superfamily Apoidea, Megachilidae and Apidae. You may encounter other families from this superfamily in your own collections. Apoidea is a large group of specialized pollen feeders. Most members have various adaptations for collecting pollen, and many are social to at least some degree.

Megachilidae, the leafcutter bees or mason bees, carry pollen in the hairs on the underside of the abdomen, a structure called the scopa. They are important native pollinators in North America, both of native plants and agricultural crops such as alfalfa. Females construct cells, usually out of leaf discs excised from nearby vegetation, in cavities in dead wood or other available materials. Each cell receives a supply of pollen and a single egg. The cell is then sealed, and another cell is constructed next to it. Several species can be encouraged to use nest boxes, promoting pollination of nearby plants. A few species are kleptoparasitic, in which case the scopa is absent.

Megachilidae is distinguished from the next family, Apidae, by the presence of two submarginal cells in the forewing, rather than three in Apidae.

Apidae

The second family from the superfamily Apoidea that we cover is the Apidae, bumble bees and honey bees. This family is generally eusocial, and critically important as pollinators for many plants. Rather than carrying pollen in a scopa, like the Megachilidae, the Apidae use a pollen basket or corbicula. The hind tibia is concave along its length, and has curved hairs that wrap over the concavity. Apidae is distinguished from the Megachilidae by the presence of three (instead of two) submarginal cells in the forewing.

Apidae is divided into two subfamilies. Bombinae, or the bumble bees, tend to be larger and stouter. They are extremely important native pollinators of both native plants and agricultural crops. Some are even semi-domesticated and used commercially to enhance pollination in field crops and in greenhouses. Naturally building nests in the ground or in protected locations, they tend to exploit old mouse nests. Research at Simon Fraser University is investigating the possibility of using mouse urine to improve the colonization of artificial nest boxes. A few bumble bee species are kleptoparasitic and, therefore, lack a corbicula.

The second subfamily, Apinae, is represented in our collection by a single species: *Apis mellifera*, the European honey bee. This bee is widely domesticated, both as a commercial pollinator and as a producer of honey, so the species has a worldwide distribution. It is, however, not native to North America.

Vespidae

Vespidae are the yellowjackets and hornets. The family also includes several paper, potter, mason, and pollen wasps. Eusociality is common in this family, but some species are solitary. Vespidae are important, and probably underrated, predators on other insects. They defend their colonies vigorously, and have acquired a menacing reputation as a result. The stinger, unlike that of a honey bee, is not barbed, so defending wasps can sting multiple times. As they sting, they also release an alarm pheromone that summons more defenders from the nest. The introduced species, *Vespa mandarinia*, the giant hornet (or "murder hornet") is in this family.

In North America, only mated females, called queens, survive the winter. The exception to this is *Vespa germanica*. in Florida. If she survives the winter, the queen will begin construction of a new nest either in the ground or suspended from a tree or other structure. She lays eggs, provisions the nest, and cares for the larvae. Once the first brood has emerged as winged adults, they do the foraging, nest development, larval care, and nest defense, and the queen continues to lay more eggs.

The wings are folded longitudinally when these wasps are at rest. This characteristic makes it extraordinarily difficult to see features of the wing venation in most pinned specimens. The eyes are usually notched on the inner margins. Another helpful characteristic is that the pronotum extends backwards to the tegulae, appearing triangular in lateral view and horseshoe-shaped from the dorsal view.

Pompilidae

Pompilidae, in the superfamily Pompiloidea, are the spider wasps. Adult females sting and paralyze a spider, then carry it to a nest where they deposit an egg. Developing larvae then feed on the still-living, but paralyzed spider. A few species are, instead, kleptoparasitoids on other Pompilidae or even ectoparasitoids on spiders.

Pompilidae tend to be dark-coloured with long, spiny legs, and often with smoky wings. The hind femora usually extend past the tip of the abdomen. The pronotum is shaped similarly to that of the Vespidae, and the forewings have three submarginal cells. The most distinctive feature of this family is a transverse suture across the mesopleuron.

Mutillidae

Mutillidae, or velvet ants, are also in the superfamily Pompiloidea. They are all ectoparasitoids of immature insects, especially bees and solitary wasps. Female velvet ants are wingless, extremely hairy, and very fast-moving. They somewhat resemble very fuzzy ants, but lack the node on the petiole that is characteristic of all ants. They are often reddish in colour. Males are winged and less hairy. This sexual dimorphism has led to difficulties in classification. Like most wasps in these later families, Mutillidae females can and do sting; the sting can be quite painful, depending on the species.

Formicidae

Formicidae, which includes all ant species, is the only family in the superfamily Formicoidea. The entire family is highly eusocial, and colonies can contain multiple castes. Generally speaking winged, or alate, reproductive individuals are produced. Mating occurs during flight, and males die shortly after. Females then land, break or chew off their wings, and find a suitable location to establish a new colony. Offspring of this single mating event are produced over the long lifespan of the mated female, or queen. Once enough individuals of the worker caste are produced, they take over all of the colony duties, while the queen continues to produce eggs. There can be some variations on this generalized life history as well.

Ants are usually readily identifiable. They have elbowed, or geniculate, antennae, and a more or less distinct "bump" or node on the petiole, illustrated below. Some subfamilies have an extremely narrow third abdominal segment, which also forms part of the petiole.

Formicidae is an incredibly diverse family. Their nest sites are often in soil, leaf litter or dead wood. In the tropics, some species are arboreal, or build temporary "bivouacs". Food sources are equally divers. Ants are important predators on other arthropods, but some species cultivate symbiotic fungi, or supplement their diets to various degrees with plant or insect secretions. Some will tend aphids and other plant sap-sucking insects in order to harvest the "honeydew" overflow. They are vigorously defensive of their colonies and the resources needed to sustain them, and are often capable of both biting and stinging.

PART XII

CONCLUSION

We have covered some of the most common orders and families that are collected by students in northern British Columbia, especially in northern British Columbia. You should now have a greater understanding of robust and ethical collection and preservation techniques, and the importance of biological collections and collecting data. You should also have an appreciation for the incredible structural, functional, and ecological diversity of insects, including how they influence all ecosystems and human society.

I hope you have also gained some basic skills in identifying common insect orders and families. Remember that the distinguishing characteristics described here may not provide faultless identification of all insect taxa, and should be applied with caution outside this course. Always feel free to consult with an experienced entomologist when a precise identification is important – and do recognize that even they may not be able to give you an exact answer!

Finally, I hope you have enjoyed the course, and that you will continue to find ways to appreciate insect diversity in your careers and in your personal lives.

This is where you can add appendices or other back matter.