## Lecture 1- Goes over course outline

Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta
Order: ex. Diptera (tera meaning wings)
Family: Muscidae (all taxa end in 'idae' for family in this course)
Genus & Species: will not be discussed in much detail in this course

Cleidograms are branched diagrams to show stages of evolution for a specific order or family (will be used in this class), reflects a hierarchy if you follow the rules of natural groups

What us an "Insect"?
Any member of the Hexapoda, 6 legged Arthropods. There are two categorical levels to Hexapoda, but there is the main one that we will focus on.
Phylum Arthropoda

- Tagma
- Hardened exoskeleton
- Paired, articulated appendages
- Open circulatory system and dorsal heart
- Ventral nerve cord

Insects divided into head, thorax and abdomen
Head: sensory and ingestive specialization
Thorax: Locomotor specialization
Abdomen: Digestive and reproductive specialization

## Lecture 2

Mouthparts of a lubber grasshopper

- Mandible
- Labrum
- Labial palp
- Clypeus
- Labrum (upper lip)
- Maxilla

Primitive insects have a single mandibular condyle
Most insects have two mandibular condyles (condyle=ball on top of the mandible)
The hypopharynx or tongue is behind the mouth.
Learning to identify book lice, there is a bulge on the top of the head (is the dilator muscles)
Flies have a lower lip developed into something like a sponge on a stick, have sponging mouthparts
Butterflies and moths have siphoning mouthparts (is the maxillae and an elongated proboscis)
True bugs/Hemiptera have piercing- sucking mouthparts where they have four elongated stylets and are the oppressed maxillae and are flanked by mandibular blades and they all fit in a sheath by the labium
Become familiar with the standard orientation of insects (proximal, distal, etc.)
Insect body parts
Notum= top of thorax: pronotum, mesonotum, metanotum

Tergum= top of abdomen

Exoskeleton and the idea that they have to molt, they can't grow with a hard shell unless they molt
Newly emerged but still soft is teneral
Epidermis, procuticle and then thin outer layer of cement/wax made out of the polysaccharide called chitin.
Moulting (ecdysis): layer of epidermal cells release chemicals that dissolve the undifferentiated top layer that is too small. The secretion of the inactive molting fluid isn't active until the cuticulin layer is up and can protect the other cells.
Remember the pieces of the legs: tarsus (made up of tarsomeres), tibia, femur, coxa, trochanter.
The top part of the thorax is the notum, the top of the abdomen is tergites, bottom parts are sternites
Main internal parts: ocellus, brain, crop, heart, salivary glands
Three major sections of the digestion system: hind gut (where the excretory process occurs, feces is formed), mid gut (where most digestion and absorption occurs), fore gut (some digestion, grinding of food, many insects rely on symbiotic microorganisms to help them process their food), also salivary glands and enzymes

Types of Insect Metamorphosis
Ametabolous (ex. Thysanura)
Hemimetabolous (ex. Odonata)
Holometabolous (ex. Lepidoptera)

Hexapod Phylogeny Primitively wingless hexapods
The tree of life for everything involving insect relationships, there is a link on courselink too
The primitively wingless hexapods "Apterygota"
Three orders of hexapods (Collembola, Protura, Diptura) are usually treated as outside the class Insecta

Order Collembola (could be considered a class): Springtails (most abundant insect on the snow surface), their leg parts are tibiotarsus, collophores, tenaculum, furcula, every segment is musculated, fewer abdominal segments than true insects, along the abdomens is a 'glue peg' which is the collophore. They have spring tail mechanisms that has a tail that can fold up and fit in the tenaculum, and when it releases it can propel them into the air. They are very abundant, small (are overlooked). The eyes are different of springtails, where they have zero to eight ocelli on each side of the head, usually on black eyepatches. The oldest fossil Collembola (which is the oldest insect fossil know) going back almost 400 million years old. The mandibles are up in a pouch/sealed mouthparts. They are probably the most abundant arthropods in the world. Can find them on water surface, snow, soil, grave sites, etc. Indirect fertilization in Collembola, where 90% of other insects have direct fertilization. Male deposits sperm away from female, she either has to find her way to the sperm or the male nudges the female to the sperm to pick it up fertilize their eggs. Some males have notches on their antennae, attach to the female antennae and they attach themselves and lead females to the sperm that they dropped. Snowfleas are a group of springtails where you'll see small flecks on the snow. Don't need to know the subgroups, just know the characteristics of the order/class Collembola.

Order Protura: Have no antennae so they have their forelegs held above their head, blind, deep in soil and very difficult to find. Anamorphic development, add abdominal segments with each moult. Is a sister group with Collembola.

Order Diplura: probably the sister group to the true Insecta but we consider them the sister group to collembola and Protura. They have two processes at the front and the back (long antennae and cerci). They are commonly found among soil, fairly obscure, divided into two suborders: Rhabdura and Dicellurata.

Amorphies of the "true insects" (class Insecta, as opposed to the superclass Hexapoda)

1. Ectognathous mouthparts
2. Antennae of the 3 true segments (annulated antennae)
3. Johnston's organ (effectively a ring that sends messages about orientation to the brain)
4. Tarsonmeres (tarsus divided)
   And others..

Insecta
Archaeognatha- Jumping Bristletails--> the most primitive insect (have old mouthparts where they only have one/ monognathous mouthparts), have abdominal appendages covered by scales (best places to find them is Bruce Penninsula with open areas of limestone). When they moult they glue themselves to substrates like rocks. Use silk strand to guide female to the sperm, indirect fertilization.

## Lecture 3 (today)

Thysanura

- Silverfish, fire rats
- Common domestic pests, minor
- Primitively wingless
- Indirect fertilization, guide the female to the sperm using silken strands
- One family of Thysanura are restricted to ant nests
- Generally have 2-3 cerci

End of primitively wingless insects

Secondary wing loss has occurred in almost every winged order because as flies move into particular environments their wings become less of an advantage and become more of a cost
Many species can have a winged morph for sex and dispersal (aphids, ants)

Metamorphosis occurs only in the Pterygota, not in the primitively wingless groups. Definition is a moult that facilitates a drastic change in form. All wing insects have to undergo a metamorphic moult between functionally wingless immature stages, and the winged adult form. Can be hemimetabolous, and develop with wings shown externally and are buds, they grow to a point and then there is a metamorphic moult to completely develop functional wings. Wings have selected for no long phase of development of functional wings. They undergo many moults but undergo one metamorphic moult. Holometabolism involves wings developing internally of the larvae, the moult to revert the outside, and then an additional moult to make them functional.
Mayflies are the only insects that moult after developing fully functional wings.
Once the wings are fully developed, with the exception of mayflies, they no longer fully moult.

Paleoptera (old wings)- first two lineages of Pterygota.
New winged insects, Neoptera, have concept that involves the wings being able to be folded
Old wings/ Paleoptera- Have no folding mechanism

- Mayflies- Ephemeroptera (femoral winged, adults are quite short lived, many emerge in the spring [may])
- Angel wings/upwings so the wings are held very characteristically, the front of the wings are triangular, the hind wings are greatly reduced, often absent--> but an not flies!
- Have two-three cerci/ tails
- Antennae are greatly reduced
- Forelegs typically longs, especially the males
- Mouthparts are reduced to non functionality, feeding is only done in the water, adults don't feed
- Mayfly nymphs with concealed gills
- Burrowing mayfly (Ephemeridae)--> make a natural group divided into several families
- Flat mayfly (Heptageniidae)--> are a natural group
- Minnow mayfly (Oligoneuridae)--> involve all of the other mayflies that don't fall under the other two groups
- Mayfly subimagos are sub-adults, with milky wings and undeveloped genitalia. No other order of insects moults from wing stage to wing stage
- Short lived: adults can live for a variety of time, a couple of hours or a few days
- Life cycle:

1. immature stages are always aquatic, in range of environments like burrows, cold water streams. They always have a series of abdominal gills, are leaf like, look a lot like insect wings
2. After aquatic nymph stage, emerges from water with milky wings, undeveloped genitalia
3. Develop clear wings, develop genitalia and have two penises, males have large eyes (turbinate) (you can tell one is a female because they have small eyes)
4. Mating typically occurs by males formed swarms, one docks on the male, they drop out of the swarm and mate- direct fertilization
5. Then female releases a bundle of eggs where the nymphs soon develop after (some female explode when entering water to lay eggs, the eggs still get dispersed, Caenidae)

- Leptohyphidae (tricorythoridae)
- Leptophlebidae 'prong gills' most likely to find around time for insect collection, abundant in ditches, eutrophic habitats
- Isonychiidae- common around here is Isonychia bicolor, black front legs, yellow emitted hind legs, nymphs are common in cleaner streams, hold front legs facing the current, inner surface has a brush where they filter feed
- Baetidae- largest group of local mayflies
- Some are so short lived that once they emerge as adults, mate and then die, never really land, they fly for minutes to hours
- Heptageniidae, in some cases the gills are expanded to form suction disks to assist in not floating away with strong currents

Typically feed on detritus, 17 families of Ephemeroptera
Discuss the life cycle of a typical mayfly, indicating where the various stages are found, including information on respiration and mating behaviour

Give two examples each of different oviposition and feeding strategies in the mayflies
Discuss the biology and importance of burring mayflies

Hymenoptera means married wings, move in synch

Paleoptera
Dragonflies and damselflies--> Odonata
Two suborders, 6000 world species, just under 200 Canadian species

- Tiny antennae's
- adults and nymphs both predators
- vision plays major role in this group
- big eyes
- massive mandibles
- dragonflies have differently shaped fore and hind wings
- folded downwards a little as a thermal regulatory technique
- very long abdomen
- direct flight where muscles are directly inserted underneath the wings
- fly with two pairs of wings independent and flight is turbulent
- Nymphs of damselflies have richly tracheated tails that serve as paddles and gills
- Dragonflies have gills at rectum, suck water in and out of rectum to propel in the water, hydraulic propulsion --> for respiration and locomotion
- Mouthparts are homologous between two suborders
- Labium, palpi are cuplike, feed by using hydraulic pressure by using pressure of haemolymph
- Dragonflies eat flies from air
- The male dragonfly grabs the female by the neck using claspers at the tip of his abdomen
- The male damselfly grabs the female by the front of the thorax using claspers at the tip of the abdomen
- Males will also hang onto females and wait for them to lay their fertilized eggs, 'guarding', they are protecting their mate from other males, if another male mates with a previously mated female, they have structures to scoop out former sperm and insert their own

At rest the mask is held folded underneath head and thorax, extending back as far or further than the front legs and in some families far enough forward to cover the face below the compound eyes. In prey capture the labium is shot rapidly forward and prey is grasped with paired, hand-like palps.

Zygoptera- Damselflies

- Pick things off of leaves
- Lestidae- spread-wings, wings are held out at an angle, not quite flat, lay eggs above the water and the hatching eggs fall into the water

Dragonflies

- Darners- Aeshnidae, aggressive insects but beneficial, good indicators of water quality
- Gomphidae- Club-tails, nymphs are usually in substrate of bottom of streams, river , ponds, they release free eggs to allow them to drop to the bottom rather than inserting above water, mate on substrates, whereas most mate on foliage or trees
- Corduligastridae

- Skimmers, most skim along water surface and release single eggs that drop to bottom. Some are basket-tails that drop in a cluster, but most drop single eggs. Colourful, abundant, range in size
- There are a lot of threatened odonates, over half are endangered and on red lists

Lecture 4

Neoptera

Plecoptera: Stoneflies

- Stonefly nymphs live in clear, cold running waters usually and well oxygenated
- Susceptible to environmental damage, are among most sensitive to agriculture, water temperature increase, and other environmental factors
- The identifying feature are the thoracic gills and plate-like gills
- Nymphs feed on variety of different things, most stoneflies feed on decomposing leaves, the biggest and most colourful of our local stoneflies are predacious and carnivores
- The adults have three tarsomeres, can be confused with cockroaches maybe but cockroaches have more tarsal segments.
- Pleco means folded, tera means wings, the hind wing looks like a fan when opened
- Mayflies emerge from nymph to subimagos, mayflies usually emerge right outside of the water, stone flies crawl onto nearby vegetation and then emerge as a teneral adults, are bad at flying so they stay fairly close to the water that they emerge from because they don't make it very far
- Mayfly has one tarsal claw, the stonefly has two tarsal claws
- Weak-flying adults with pleated hind wings
- Summer stone flies are colourful, larger and carnivorous around here. The nymphs in the winter looks drastically different, smaller, more of a narrow body, feed on algae. They feed as adults unlike mayflies.
- The phylogenetic tree is pretty much separated from southern and northern hemisphere species which is quite odd and different compared to other species. Summer stoneflies are a special sub derived group that have a specialized lower lip and are predacious.
- Differ with communication strategies. Males have structures on abdomens called hammers and communicate by hammering on substrates. How do they find their mates? Most commonly assumed that that is how they communicate with their mates. Drumming with the abdomen is a special stonefly trait.

Summer vs winter stoneflies

Summer:

- Carnivorous nymphs
- Non-feeding adults
- Eggs with anchor plate

Winter:

- Detrivores as nymphs
- Algal grazers as adults
- Eggs with jelly coat

Dictyoptera- include mantis, cockroaches, termites

Mantis

- Easy to recognize because of raptorial forelegs to grab prey

- Big eyes and mobile head to spot prey
- Stretched legs and head away from body so that prey does not harm the predator when eating it
- We have two species in Canada but none of them are native- common brown and common green mantis but they are European Mantis
- Both lay eggs in similar egg masses called ootheca that look like Styrofoam sheets that are made out of lamellae. At arb we have Chinese and European mantis. They have diapause which is a mechanism of arrested development, in most overwintering insects, length and days combined with increasing temperatures with break diapause. Gather golden rods in late February and then it will break diapause and you can use.
- Common perception is that mantis female eats male after mating, but it is not general in mantis'.
- All are predators and normally feed on other insects, do occasionally feed on lizards or birds
- Uniform group in terms of morphology and biology

Cockroaches: Blattodea

- Primarily tropical group, are very diverse
- Parcoblatta- wood roaches, native to Ontario, some are wingless and some are fully winged. Will find adults or shiny ootheca
- Invasive roaches: Periclinetta (Australian and American roach), Blatellagermanica (German roach)
- Associated with human kind--> cinanthrophic ****
- Cryptocercus: North American roach but not in Canada, will find in groups and feed on cellulose and facilitate digests cellulose by eating each other's feces, and the feces digest the cellulose for them afterwards
- They are the ultimate omnivores
- Susceptible to desiccation
- Some carry ootheca around, others deposit on substrates. Ootheca is common to find when you rip apart logs.
- Oriental roach, American roach, German roach and Australian roach--> Northern Hemisphere roaches
- Isoptera/termites arise from the middle of the cockroaches, the cockroaches without the termites are paraphyletic

Isoptera- Termites: eastern subterranean termites that are native to Ontario

- Most reproduce routinely by producing winged males and females, go on massive flight, go to ground, mate, shed their wings, male and female will establish new female. The male stays with the colony and periodically fertilize the female, and will continue to reproduce. Feces of the queen include chemicals and beneficial microorganisms to be able to digest things like wood/cellulose.
- In Ontario they spread underground
- All Isoptera are social. No other insect order is entirely social. Eusocial to be more specific, they have cooperative care
- Include caste for defense (called soldiers) and can take a variety of different forms, most are seen as large headed forms. Some have long mandibles that snap
- There are also glue squirters/nail heads with mechanism for defense against ants
- 'super termite' - invasive introduced species, millions of individuals per colony
- All social
- Workers, soldiers and alates, both sexes
- Two primary reproductives- king and queen
- Caste differentiation regulated by anal trophallaxis
- Symbiotic organisms digest cellulose

- Small order (2300 spp) but very important in tropics and grasslands

Lecture 5

Dictyoptera (Blattodea, Isoptera, and mantodea) last class

Dermaptera (skin wing) refers to leathery forewings of the Dermaptera, all have moveable forceps, more hooked in male than female, hind wings are normally functional (not always) and folded under the hind wings. Dermaptera is supposed to be the more tropical group, but you can still find some up in North America. Common omnivore, they eat flowers, can be beneficial insects in apple orchards, but are mostly pests

- Interesting about earwigs is maternal care, they deposit clutches of eggs, mostly in soil sometimes underneath rocks and logs. The mothers will guard the eggs until they hatch and are nymphs.

Phasmatodea- stick insects

- Group which is diverse, interesting and attractive in the tropics, in North America we have one native here : Diapheromera femorata, they like oak trees
- Feed on foliage, local spp feeds on oak and sometimes raspberry
- Mating strategy: male protects paternity by having long copulation, and the female doesn't have any maternal care, the female drops her eggs from up in the trees
- The eggs in many species have things attractive to ants, then they pick up the walking stick eggs and store them in their nests that saves them from predation and other disturbances

Web-spinners- embioptera (look up later)

- Primarily tropical group, and only in southwest united states
- Spin silk out of their tarsus
- Use and production of silk across the Insecta- labial silk, silk from excretory glands, silk from out of the four tarsus (rare)
- Use silk for tubular shelters in this case, usually hidden under silken webbing under leaves, they scurry up and down hidden under silk shelter
- Can be found in wing and wingless forms
- Small order

Grylloblattodea

- "Canada's national insect" emblem insect on crest of entomological society of Canada
- What is it? Most recently discovered order
- First discovered in western Canada not too far from Banff, worked at ROM, described as new order
- Described in 1914
- Common name is glacier bugs or rock crawlers, active at very cold temps, go out at night on ice, and prey on other insects that are immobilized on the cold icy temperatures
- Wingless
- Can be called Notoptera, considered to be encompassing term of rock crawlers and most recently discovered/described order of Mantophasmatodea (were in collections in southern africa for years but didn't know what to do with them, recently collected some in a mountain ranges, then described new spp.) because it looks like a cross between a walking stick bug and a mantis

- Some believe they are sister groups, and so closely related that it is argued that they should be in the same order
- Therefore: Notoptera= mantophasmatodea and grylloblattodea are within this order

Zoraptera- angel insects, don't occur in Canada (zor=pure, tera=winged) or pure and wingless when first discovered, misnoma

- Eyeless or with eyes, also wingless or winged forms
- Two tarsomeres
- Some have apterous forms (wingless and eyeless) and with same aggregation (developed wings, fly and then shed their wings but have eyes)
- Considered to be rare insects but like moist fallen logs so people just need to look in the right places
- Most obscure insect we will talk about today

Orthoptera (jumping straight wings in Latin)

- Modified hind legs and straight forewings
- 40 families (25 k spp), 10 families in Ontario (134 spp)
- Grasshoppers, crickets, katydids
- Two suborders:
- Suborder Ensifera
- Long-horned orthoptera- crickets, katydid and their relatives
- Stridulate using a file and scraper; the music is heard using a foreleg ear; some are right winged and some are left winged
- Gryllidae- the true crickets family- field crickets, long antennae and long sword-like egg laying device. Their mechanism of stridulation, the males amplify sound using burrows, teeth, file, scraper and two wings to make sound
- Most crickets are omnivores
- Often nocturnal
- Usually have long appendicular ovipositors (egg laying tubes on females)
- Complex courtship (based on stridulation)
- Crickets are important in Asian culture- buying elaborate cages to hold the songs, can be used for fights and betting situations
- Crickets can now be a potential protein source, primarily for pet food but is not coming to light for livestock and people - not as efficient as flies but whatever
- Can secrete attractive fluid on their backs that females would want to eat that comes from a specialized gland
- Rhaphidophoridae- cave and camel crickets
- Some spp in this genus that are important cave inhabitants, move significant nutrients into the cave environment
- Are wingless
- Gryllacrididae - leaf rolling crickets--> sub family - not true crickets
- Gryllotalpidae- mole crickets--> not true crickets but we call them crickets anyways
- Mormon crickets are so abundant and big that they can actually cause accidents on roads, etc. They eat everything, are omnivores, can also eat a crap ton of crops so it can be a big pest problems. Come in cycles of abundance.
- Phase polymorphism - shield backed orthoptera of winged and wingless forms
- Tettigonitidae- Katydids and their relatives in terms of sex- male deposits white mass that sticks out of female genital opening- being left there as a nuptial gift- nutritious spermataphylax- female

eats it to keep her busy and is a transfer of protein to female and eggs to increase survival of reproduction
- Can have pink morph

Protective coloration in orthoptera

- Suborder Caelifera- short horned grasshoppers
- Acrididae- all in lab
- Push whole abdomen in soil, at apex of abdomen they deposit egg masses
- Have pink morph
- Subfamilies: Band-winged grasshoppers, Sedge grasshoppers,
- Locust
- Melanoplus --> genera--> 90% of grasshoppers around here are in this genus and includes species called Rocky Mountain Locust- major pest in western north America before 1900, enormous periodic swarms, extinct since 1902--> because it is a cyclous pest, would be innocuous in the mountains and then appear in mass numbers. Locust is a term that is used to describe phase polymorphism. Two forms: solitude form and gregarious form. Some swarms preserved in glaciers. One swarm was reported at 98,000 square miles in size greater than the area of California, weighing 27.5 million tons, and consisting of some 12.5 insects. We caused it to go extinct through accidental manipulation of the environment due to anthropocentric reasons- agriculture
- Desert Locust- swarms can be huge- up to hundreds of sq km

Locusts: various acrididae that exhibit phase polymorphism

Lecture 6

Hemiptera- True Bugs

- Suborders: sternorrhyncha, auchenorrhyncha, and heteroptera
- Hemimetabolous insects with piercing-sucking mouthparts/elongated mouth parts
- Under 4000 Canadian species
- Stylets have two knife like elongated pieces for cutting/piercing and in the middle have two channels 'slurp and suck holes'
- Inject saliva (anticoalagent, dissolve host tissue) through salivary channel, and then there is a food channel

Bedbug- Cimex lectularius cimicidae

- For much of recent history, the term bug referred to the bed bug
- Wingless, bloodsucker
- The term bug got broadened from one spp to a whole order of Hemiptera
- Eggs are laid in protected places and are hard to find, can see black dots which are the feces and they really smell
- They also feed on bats in the wild
- Traumatic insemination in bed bugs- male equipped w intermittent organ and has to rip part of female's abdomen aside to inject semen. Females have sponge like organ is thought to protect female from damage during insemination. Odd thing is that males have evolved to have same sponge like organ, and males are frequently ripped open by other males. Evolved because of extreme male competition to inseminate a female. Females develop ways of avoiding unwanted

mating, but results in sexual conflict and weird morphologies. Females were starting to imitate males to avoid unwanted mating- normally see this in damselflies.
- Most bed bugs can be mistaken for swallow bugs- look like them but have a golden fuzz on body which makes them different- fall from swallow nests, end up on people's porches sometimes

Order Hemiptera- Suborder Heteroptera
- Half leathery wings and half membranous distal part- have exposed __

Shore, surface and Water Bugs- Semiaquatic Hemiptera
Gerridae- water striders
- Recognized by short fore legs and elongated hind legs
- Tarsal claws are moved up above the apex of the leg so they are not puncturing the surface film
- They can feed on struggling/drowning/dying insects
- All aquatic and semiaquatic insects are predacious (with certain exceptions)
- In most cases, surface insects are apterous/wingless
- Normally occur in apterous form but sometimes around here they produce a winged/dispersal morph
- Hydrometridae- water measurers- like tiny lil walking sticks on water, look by duckweed
- Veliidae- riffle bugs- group includes fast and slow water species, and crazy morphology things, broad shouldered, move incessantly, sit below riffle to feed on insects that are washed down from falling into the water, extremely common, wide thorax, at apex of leg is a fall near end of the foot that is a modified feather like tarsal claw
- Mesoveliidae- water treaders- very common but only one species of this in Ontario, are apterous but occasionally macropterous.
- Saldidae- shore bugs- always winged, most are fast and hard to catch, closed loops in wing membrane
- Gelasticoridae and naucoridae- strictly aquatic bugs
- Most awuatic heteroptera allows them to disperse by flying over terrestrial land to other water but get distracted by artificial light

-->Lethocerus (one of two subfamilies) In this group the investment is large, need to protect paternity vigorously and are more choosy of females for mating. Mating occurs repeatedly and over a long period of time (similar to walking sticks where the male hangs on over a longer copulation)
--> belostomatidae: giant water bugs- (one of two subfamilies) diverge in interesting ways and will help us understand their natural history. These have simple oviposition strategy, lay eggs on emerging vegetation or logs sticking out of the water, and the males take care of the eggs. They mark the eggs with glandular secretion, protect them and keep them moist -- paternal eggs.

Nepidae
- In ontario they all breath on the surface through different morphological adaptations

Notonectidae and Pleidae (backswimmers)
- Has white back side so that fish looking up would see a white back and a white sky (camo a lil)
- Fly from pond to pond, could get them in slow moving rivers and streams, when they fly from pond to pond they can end up in pools and can bite if picked up
- Forewings hardened and extended to the end of the body and line up straight, can be confused with a beetle but are distinctly different when you look at their mouthparts
- Can live in different depths, nice to work on for science but don't handle them carelessly

Corixidae- water boatmen

- fantastically abundant
- Only group that stray from generalization of all aquatic insects being predators
- Have beaks stylets that feed on wide variety of material including plant and animal material
- Distinguished because they are flattened, softer than backswimmers, flat dorsal surface and a distinct pattern, and degree of convexity (backswimmers have elongated beak, differentiated factor because for water boatmen it is hidden under a triangular part)
- Eggs can be harvested and eaten as pet food and in some countries can be prepared for humans (corixid caviar)
- Have rows of pegs, species are hard to identify because the keys suck, there are pegs on the forelegs that are used for communication between males and females for mating purposes

  Questions on midterm maybe
- Compare and contrast backswimmers and Corxidae
- Name three families of aquatic Hemiptera and three families of shore or surface bugs. What do they eat? What are the usual morphological differences between aquatic and semiaquatic bugs?
- Function of wings, occasional occurrence of winged bugs can be discussed
- Describe the life cycle of two different Belostomatidae (giant water bugs), contrasting oviposition and care of the eggs. (the two subfamilies discussed)

Other lineages of Heteroptera
- All have visible and free beak, Homoptera have thin inconspicuous beak that arise between the four coxids

Heteroptera have division of leathery and membranous parts of the wings, and are one of three suborders of Hemiptera

Pentatomidae- Stink Bugs
- Is technically a superfamily
- Main lineages of heteroptera
- Shield shaped bodies, and eggs are often found in clusters and have lids/furcula
- Are predacious or phytophagous (feed on plants)
- There are glands on side of body (different on nymphs and adults) act as defensive compounds
- Phytophagous- can tell by looking at beak because it is slender and close to body whereas predacious are larger and obviously seen
- One species to know is the Brown Marmorated Stink Bug is a highly holiphagous pest (wide variety of hosts) introduced from china about 10 years ago, is common in Beijing and now in Southern Ontario. Can be found in overwintering clusters in garages
- Native pests like berry bugs, but not as significant as bmsb
- Have elaborate parental care, and they sweep antennae over the cluster of eggs to fend off predators and pests

Lecture 7

Heteroptera- true bugs
Ebony bugs- thyreocoridae are actually stink bugs/pentatomidae- is commonly mistaken for a beetle but does not have the straight line on the back pentatomoidea is actually a superfamily

Reduviidae- Assassin Bugs

- Transverse groove on top of head
- Characteristic weapon-like beak- used to impale other animals
- Mostly impale other invertebrates but there is one subfamily that can suck vertebrate blood
- Reduvius personatus- bed bug hunter where the nymph is common in houses, their backs sticky and lint can stick to their backs- most common insect found in light fixtures- adult
- Most overwinter as eggs, in clusters or Zelus spends winter as a mature nymph
- Painful bites and can inject you w small amount of venom (be careful when handling predacious hempitera)
- Includes a group of related species that is entirely temitpherous (hang out on termite nests) and when the nest is ruptured, they wait and stab the termites. Some of them fish for termites
- Triatominae "bloodsucking cone-nose" know by name because they are the first medically significant taxon that we have encountered so far in the course, also known as kissing bugs because they literally suck face. They are vectors of a major disease- Chagas' disease (Triatoma infestans) from texas south to the new world is distribution- in most cases is asymptomatic but can cause lymph nodes, headaches but in the long term can result in swelling of the heart and death. They don't only drink blood of people, it can be a variety of small vertebrates like dogs and guinea pigs, rats. When they bite people but bit other small vertebrates first. If you get bit there is a sign of Ramona, characteristic swelling near the eye, and if you rub your eye, then it can reach your eye
- Thread legged bug is a subfamily

Chagas' disease

- Over 100 mammal reservoirs
- Vectors, reservoirs and parasite occur north to Pennsylvania; disease is transmitted by bugs from Texas south to Argentina
- Millions infected
- Disease can cause heart malfunction, weakness, fatigue and sometimes death
- Darwin's disease?- because in the voyage of the beetle he writes about finding a giant bug, putting it on the table and getting bitten, puncturing his finger and blah blah blah inferred that the shit he complained about later in life was due to the bite from the Reduviidae

- Phymatinae- Ambush bug (widely treated as Phymatidae)

Distinctive looking bugs, know that these are common ambush predators on flowers everywhere- normally on goldenrods

- Nabidae-damsel

Considered to be a significant group of beneficial bugs, no detrimental aspects, useful in orchards where they eat pests

- Tingidae- Lace bugs

Lacy appearance of the wing covers, really can't mistake them for anything else
Easiest place to find them in the summer is any basswood tree

- Aradidae- Flat bugs

Family that if you know the common name you can identify them
Can suck out the contents of fungi, can find them under bark of dead trees, some are quite rare

- Lygaeidae- Seed bugs

Can be small and large milkweed bugs
Large milkweed bugs are commonly used in labs

- Chinch bugs in the lygeoididae- commonly found eating at the base of common grasses
- Berytidae-stilt bugs (charismatic, spindle shaped antennae and swollen legs)

Coreidae- leaf-footed bugs
Euphorbia bug- specific to canada's oak savannahs
Recent immigrant to Ontario- from Western North America--> western conifer seed bugs, overwinters as an adult and feeds on conifer seeds
Coreidae- the squash bug
Scentless plant bugs/ boxelder bug- Rhopalidae- minor nuisance, not a pest, build up inn high numbers that the public notices, have no scent glands on the side of the thorax (thats why they're called scentless plant bugs)
Alydidae- broad- headed bugs, common on golden rods
**Anthocoridae- minute pirate bugs, unusual, can be used as a living pesticide, will eat the eggs of other insects, identified by the notch on the inside of the lineated wing

Miridae- Plant bugs , 9/20 heteroptera will be this group, most common and diverse group in the heteroptera order
No simple eyes, notch towards the wings, cuneus, two closed cells/loops beneath the wings

- Tarnished plant bug- Lygus lineolaris one of the most common insects of ontario, serious pest on variety of crops, feed by sticking beak into plant and whipping up a slurry, then feed on the slurry- in fall can collect in the thousands, polyphagous pest
- Beneficial insect (showing diversity): used in biocontrol in greenhouses because it is considered a biocontrol insect

Suborder Auchenorrhyncha- cicadas, leafhoppers, planthoppers, and relatives
The active homopterans
Short antennae

- Front of the head with muscles to form a pump for feeding

- Cicadidae: cicadas
- Large body, clear wings, short antennae, piercing beack
- Suck sap from roots as nymphs (suck xylem), the sap that they suck is nutrient poor and they are able to survive with the help of microorganisms/symbionts
- Nymphs crawl up out of the soil, some sit in mud turrets, the nymph will go up on tree trunks/ foliage
- 7 year development time under soil around here, very short --> not synchronized
- Males have tymbal on base of abdomen which they vibrate with muscles, amplified with ear drum and hollow abdomen
- Common ones are dog-day cicadas
- Interesting ones are the Magicicadas (not in Ontario) where they are on the border of windsor--> interesting genera of all organisms- occurs in eastern north america, seven species, 4 have 13 years life cycle, 3 have 17 year life cycle and their emergences are synchronized--> broods always come out at the same place at the same time every 13 or 17 years. Come out in the millions, deafening sounds--> brood X will have to wait until 2021

- Predator saturation: if you emerge in synchrony every two years the predators can adjust but for 13 and 17 years, the predator can't track that so it catches them off guard. It is also because they are extremely loud so they need to be as unpredictable as possible
- Cicadas belong to a superfamily called the Cicadoidea- don't really look like cicadas but if you listen to them closely they have the same mechanisms of communication

Leafhoppers- Cicadellidae

- Recognized by a row of bristles
- Have characteristic motions on foliage
- One pest is the potato leafhopper, pest of alfalfa
- Suck out sap and reduce the vigor of the crops but also by vectoring certain diseases that would be transmitted during feeding

Cercopidae- Spittlebugs

- Blows fluid out of butt and air is being pumped out of tube on body, makes spittle mass- bubble shelter, they develop inside of the shelter
- There are some predacious flies, wasps, etc. That can eat the spittle bugs but they are fairly good for defense

Membracidae- treehoppers

- Often associated with ants, nymphs digest sugary waste fluids
- Some have distinctively spiked nymphs
- Tops can adapt to look like they're an ant/ carrying an ant on top
- Diverse in tropics

Lecture 8

Fulgoroidea- planthoppers
Distinguished from the siccadoidea from looking where the antennae is
Location of antennae will allow you to recognize this group
Found on trees, shrubs and herbaceous plants
Antennae are found underneath the eyes and are extremely thin

- Typical family is the Fulgoridae: large and charismatic bunch, some called peanut bugs which are fricking adorable and have a face that looks like the shape of a peanut, used to be called lantern bugs because of a past misidentification but do not bioluminescence. Thought that if you're bitten by these you'll die but that is also a myth.
- Spotted lanternfly- new pest in eastern north America- attacks grapes, apples, stone fruits, etc. same general area as BMSB, EAB, Asian longhorn- not pests here

Hemiptera
Suborders
Sternorrhyncha, auchenorrhyncha (neck beak) and heteroptera

Sternorrhyncha- translates to breast beak -refers to fact that if you look underneath the bug it looks like the 'beak' comes out from the breast

- Differ by having long antennae, smaller, softer, less active insects
- Aphids, scales, white flies, mealy bugs, jumping plant lice
- Aphids make up a super family but majority are in the one family
- Honeydew is ejested out of anus and is sweet

- Aphids often have close relationship with ants because the ants often feed on the honeydew and the ants then protect the aphids- mutualistic arrangement - primary role of cornicles is defensive- aphids are among the most defenseless insects out there and survive by reproducing in mass numbers
- Produce alarm pheromones- may drop from the plant, may recruit ants to come protect them, can produce sticky substances that come out of the ant's antennae, and are nice characters to recognize because of their big booties
- Significant because they feed on plant and diverse and abundant and in temperate regions they are major plant pests
- Among very few groups that show reverse latitudinal diversity pattern- diverse in north and south temperate regions - sawflies also follow the same trend
- Often in clusters and groups
- Injects saliva and then sucks up phloem and sap- the secretions they pump out form a feeding sheath which can cause damage to the plant, can also inject something into the plant (act as a vector for pathogens and viruses) and they become the most important vectors of plant diseases
- Has mass dispersal flights mid seasons - example is black mass at blue jays game story
- Major pests: soybean aphids, rosy apple aphid, black bean aphid, milkweed aphid
- Life cycle: in winter, would be overwintering as eggs on things like buckthorn, in soring the eggs will hatch to flightless females, then build up population to wing generations, periodically give rise again to wing females, will fly from crop to crop, in fall will produce winged females and males, then mated form gives rise to an overwintering egg (look up soybean aphid lifecycle picture)
- Viviparid (gives birth to live larvae or nymphs)
- Strategies: waste energy on males, eggs and wings only when necessary which allows them to build up the population with incredible speed (usually parthenogenetic, viviparous, and apterous) and often alternate hosts
- Aphids are consumed in great numbers normally by a large number of specialists- lady bugs, flower flies, stink bugs, ground beetles, parasitic wasps, damsel bugs)

Galls can be considered a custom made house for the insect made by the plant and instructed by the insect, which even involves the plant providing food for the insect - gall forming insects are treated as plant parasites

Other families of Sternorrhyncha are smaller than the previously mentioned adelgidae

Psyllidae- Jumping plant lice- look like tiny cicadas but with long antennae

- Ex. Hackberry psylla: every hackberry tree has characteristic nubs that are galls for psyllids/ jumping plantlice

Alyrodidae- whiteflies

- Not very big group but one you need to know because they are economically important, pests, major impact in Ontario is in greenhouses, elsewhere can be very abundant on a variety of crops
- Have peculiar nymphal stages where their wings are late to emerge

Coccoidea- scales, mealy bugs, and relatives

- Generally sessile or almost sessile (fixed to one spot or not very mobile)
- Have typical life cycle involves winged male with two wings, short lived, non-feeding, serves to mate with female and that's it. Females emerge from eggs as crawlers, no wings, will crawl to point where they will feed, will mate with male, and then will settle down and degenerate. Female will snake her beak dying in plant tissue, loses antennae and legs and just remains dead on the host plant.
- Mealy bugs stay mobile throughout female life, culminates in amorphous blob, common species on houseplants

- They also produce honeydew and ants commonly are also associated with these insects
- Cottony part is eggs mass
- Biggest scale on campus/Ontario is a magnolia scale

Practice questions
Discuss the biology of cicadas, contrasting Magicicada with more widespread Tibicen
Describe the biology and life cycle of Ceropidae, comparing them with Cicadellidae
Describe mouthparts and feeding in Sternorrhyncha and link their feeding habits to their economic importance
Describe the life cycle of a typical scale insect
Preparing for the exam-read the textbook
Remaining Hemipteroids

Thysanoptera (hairy wings)- thrips
- Most thrips don't have wings
- Have asymmetrical mouthparts- left mandible developed into punch and suck tool, always have torpedo shape
- Have bladder feet - are the only ones with those feet- malleable bladder foot for leaf feeding insects
- 2 larval and 2-3 pupalike stages, some reproduce without mating
- All described genera of thrips are haplodiploid organisms capable of parthenogenesis
- Can find in greenhouses this time of year, in summer can find on composite flowers where two tailed thrips are very commonly found to feed
- Some thrips are predators, feeding on other subcortical insects
- Pear thrips have been considered a serious forest pest only recently

Psocoptera (booklice and bark lice, and bark flies)
- Swollen front of head, not sucking insects, mandibles rub on lichens and similar material, grind it up
- Not pests, don't bite
- Diverse group
- Couple families are typically wingless (booklice)

Phthiraptera

Lecture 9
Was absent but studied Trichoptera/ Caddisflies Chapter 7 pages 161 and 162

Lecture 10
Intro to hymenoptera
Sawflies and the parasitoids

- Name means married wings
- Row of hooks on anterior wings, hook onto the fore wings and they combine/marry together
- Usually have 4 wings, generally have 5 segmented tarsi, body usually hard and shiny, very generalized holometabolous insect. Basal lineages of hymenoptera are very generalized
- Are haplodiploid
- Females- fertilized eggs (diploid)

- Males- unfertilized eggs (haploid)

Suborder Symphyta
Sawflies, horntails, and relatives
Abdomen and thorax broadly joined
Suborder Apocrita
Ants, wasps and bees
Petiolate (wasp-waisted) abdomen

Suborder Symphyta

Foliage feeding/plant feeding
- Tenthredinidae: larvae look remarkably like caterpillars (but there are no crochets and single simple eyes), have prolegs have greater number of prolegs. Pear slug is a larvae, pests of fruit trees  where they skeletonize the leaves.
- Diprionidae: conifer sawflies, when you disturb them at the tips of pine trees, they throw their heads back and release gross smelling saliva. Can find them now but as brown silken cocoons stuck with twigs. Pupate in the cocoons.
- Pamphilidae: pine false webworm, feeds on pine underneath a silken shelter, always looks dirty because its filled with frass/bug poop
- Argidae: birch sawfly, easily recognized by long antennal segment

Sawfly refers to ovipositor in female sawflies can be used to slice/saw in vegetation to insert eggs. Eggs inserted with ovipositor
- Cimbicidae: rod bodied adults, no wasp waist. Larvae squirt defensive fluid, common on willow trees

Endophytic or inside feeding sawflies
- Siricidae- horntails: Broad abdomen and thorax, ovipositor is used to inject eggs inside stems, tree trunks, and other kinds of plant material. Horntails use ovipositor to inject egg and symbiotic fungi that the larvae will feed on later. Most likely to be seen on maple, take a long time to oviposit.
- Xiphidriidae: will find feeding on a variety of conifer trunks
- Cephidae: normally found on grasses mating and ovipositing

Parasitic sawflies
- Orussidae: parasitic wood wasps, feed on other organisms--> is actually a parasitoid, sister group to rest of hymenoptera/apocrita
- Artificial group

There are many parasitoid (feeds on one individual/host) insects, there are few parasitic insects, predacious insects would be one that feeds on multiple individuals.

Many lineages of Apocrita are parasitic--> wasp waist
Explained as a mechanism for ovipositing on a host, more mobility over symphyta. The waist is constriction between two thoracic segments

Suborder is divided into parasitica (several basal lineages, at least primitively parasitic) and aculeata

Parasitica (underlined is superfamily and any under that are in the superfamily)

- Most parasitoids are a hymenoptera or diptera but coleoptera, lepidoptera include some parasitoids
- Can be argued that there are more parasitoid hymenoptera than any species in a single taxonomic group
- Ichneumonidae: must know, identify them at superfamily level because they are huge, over 60,000 species- eat host from the outside, simple and basic parasitoid strategy--> idiobonts.
- Braconidae: Peristinus attacking Lygus nymph as example (tarnished plant bugs), generally smaller that ichneumonids, both have common morphological segments.
- Chalcidoidea: one family is fairyflies, reduced to thin fringed hairs for wings. Pteromalidae, can control house flies, majority of success stories for biological control are Chalcidoidea. Aphelinidae is a parasite of whiteflies (reproduce my thelytoky, unfertilized females producing more unfertilized females), and parasitized hosts usually turn black. Commonly used for biocontrol of whiteflies in greenhouses.
- Eurytomidae: parasitoid of goldenrod gall fly. If there is a pupa on the edge is the fly. If there is larvae in the middle it is a parasitoid of the fly, killed the fly.
- Proctotrupoidea
- Diaprioidea
- Platygastroidea: largest group of egg parasites, can hitch a ride on adults and then when the eggs are laid will land on the eggs
- Evaniidae: ensign wasps. Parasites of cockroaches
- Gateruptiidae: parasitoids of bees and wasps
- Eucharitidae: parasites of ants, active first instar larvae, hitch a ride into ant colonies
- Agaonidae: fig wasps, have famous life cycle. Obligate pollinators of certain kinds of figs. Female fig wasps lays eggs in fruit, developing larvae form galls inside fig, will either develop Into flightless males or normal females. The males will emerge by chewing tunnel/passageway and mate, then dies. Female uses passageway to leave, flies to another fig and them lays eggs.
- Trigonalidae: if the eggs are eaten by a caterpillar and if the caterpillar is invaded by another parasitoid the trigonalid larva will parasitize the other parasitoid. Otherwise it will die.
- Pelecinidae

- Idiobonts, like ichneumonidae, drilling for a host sawfly larva, prevent further development of the host, and this develop on a single host stage. Most idiobonts are ectoparasitoids.
- Koinobonts, like there braconids pupating outside the sphinx host, allow host development after oviposition. Note the chalcid Hyperparasite on one of the braconid cocoons. Host specificity is greater, because if you are to become specialized enough to live w host without killing it, you need to possess this specificity. There are levels of specialization.
- Hyperparasites attack other parasitoids
- Parasitoidism
- Solitary: 1 parasitoid laid by a female into host
- Gregarious: many eggs or 1 polyembryonic egg that divides and hatches into many individuals

Lecture 11
Cynipoidea- finishing up hymenoptera

Parts of hymenoptera- mesosoma, metasoma

Cynipoidea is a super family to parasitica but not really
Are parasitoids around here

- Ex gall wasps
- Short lived, small, inconspicuous but will definitely see the galls
- insect spp specific structures that provide shelter and food for the larvae
- majority on oaks and roses
- They don't shit where they eat- desiccation delayed until emergence from gall

Group defined by particular characteristic- modification of the ovipositor where it is used to sting rather than to deposit eggs--> Aculeata

- First few lineages are still parasitoids
- Simplistically divided into three superfamilies:

i)Apoids
ii) vespoids
iii)chrysidoids

**Chrysidoidea**

- Bethylida
- Group of wasps not common in nature but are common on Guelph campus
- Wasps are specialists on pest beetle on campus to combat them, shave patches of the beetle, sting beetle and then lay eggs on shaved part
- Egg is delivered from the base of the sting
- Drynidae
- Parasitoids of homopterans
- Front legs with pinchers
- Use the pinchers to grab and hold prey, then sting the prey and lay eggs in host. Larvae emerge in host then stick out over time
- Chrysididae- Cuckoo wasps
- Walk into another wasps nest protected, roll into ball as defense mechanism, will put eggs on host larvae and will develop at ectoparasitoids
- Underside of abdomen deeply concave to curl into ball
- Kleptoparasite, mostly but not entirely on aculeate hosts --> insects that steal their host's food

Traditional classifications recognize two major lineages of Aculeata: Vespoidea (thought to be an unnatural group now) and Apoidea

**Vespoidea**

- Pompilidae- Spider wasps
- Larvae develop on spiders
- Different from other parasitoids because of their sting
- Most abundant in open sunny areas
- Capture spiders, immobilize them with sting, trim legs off spiders, drag them back to protected nests, lay eggs, larvae develops as an ectoparasitoid
- Thynnidae (Tiphiidae)
- Large wasps with large stinger, almost all parasitoids of subterranean coleoptera

- Go into beetle larvae in soil, sting it and lay eggs on it
- Mostly on scarab larvae but also on tiger beetle larvae
- Look like ants, not ants because ants have scale like petiole and the open antennae differentiation
- Jump into the burrow entrances, beetles grab the wasps, wrap their abdomen around and sting them and lays their eggs, then moves on
- Presumable completely immobilizes the host and that's what releases the jaws
- Scoliidae- parasitoids of white grubs and beetle larvae
- Morphologically have shattered "safety glass" segments on ends of wings
- Mutillidae- velvet ants
- Closely related to spider wasps
- Not ants, they are wasps
- Wingless females
- Males cannot sting (because they don't have an egg laying device/ovipositor)
- Females are very hard (esp to pin)
- Potent stings given they are not a social Hymenoptera
- Major parasitoids of other stinging Hymenoptera
- Some wasps stock nests with paralyzed preys and velvet ants try to eat those nests or steal them and need to be well armed
- Vespidae
- Linearly folded wing and triangular pronotum - only applies to two subfamilies
- Pollen wasp: subfamily of Vespidae recognized by flat wing and antennae, instead of gathering high protein arthropod food, grabbing immobile protein food- pollen. Larvae develop on gathered pollen. Everywhere else except eastern north america
- Potter wasps: Eumeninae: like pompillids, sting prey and bring back to nest, are specialists on lepidoptera. Make nests on mud, stock with paralyzed caterpillars. Called potter wasps because the mud nests look like pottery on foliage and shit
- Hover wasps: first group to see eusociality in hymenoptera- nests can have one or many females. Nests made of masticated plant tissue or paper
- Polistinae: social, all make nests--> paper nests, masticated plant fibers, don't sting and paralyze prey they sting and kill prey, rip in shreds, bring them back to nests, chew them up and feed to larvae. Adults put liquid food right into the larvae's mouth, no males involved, fertile workers, one queen, overlapping and cooperative care of ages
- Vespinae: Yellow jackets and hornets, most likely hymenoptera to be stung by, defend their colonies very aggressively. Queen stores sperm, in spring she becomes fertilized, lays eggs, give rise to massive colony later in the summer. Will forage for herself at first, and then after first hatch the queen is just an egg laying machine. Die off in the fall and the only one that survives is the fecundating queen. Bald faced hornet is very aggressive native species, have nasty sting and move in on you in great numbers.

**Apoidea- bees and relatives**

- Short pronotum with tab on the side, contrast from triangular pronotum in vespoids
- Sphecidae and Crabronidae
- Sphecids are two genera of mud daubers. They gather mud, moisten the mud, bring it back to make nest. Then stock nests with paralyzed spiders. One takes over old nests whereas the other builds nest from scratch. Prey are paralyzed but still alive but only eat a little at a time, but ultimately killing them.

- Sphex feed primarily on Enciphera, male is bigger than female but they prey and gathering aculeates, males often compete with females, males are large and equipped to fight with each other for females.
- Crabronidae: can hunt cicadas (called cicada killer), specializes in group of beetles one is the emerald ash borer and exert control on beetles and hunt them extremely effectively so we can use them for biomonitoring purposes
- Bees= Anthophila: transition group that goes from stinging and killing invertebrate hosts for protein but instead collects immobilized protein of pollen.