Bio 26L, Laboratory 9, pg 1.

EXTANT ARTHROPODS: CRUSTACEANS, CHELICERATES, & INSECTS

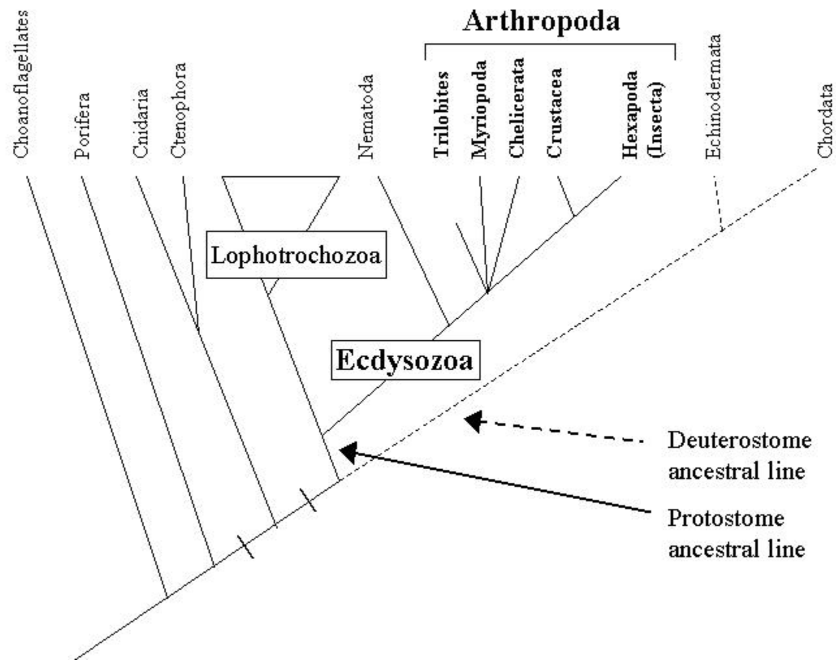

Figure 1. A possible Phylogeny of Animalia, based on rRNA data

LEARNING GOALS:

1. To learn the characteristics shared by members of the Arthropoda, and to know synapomorphies of each of the major Arthropod subphyla: Trilobites, Myriopods, Chelicerates, Crustaceans, and Hexapods (Insects, etc.).
2. To learn some of the major subgroups within each of these subphyla, and learn some characteristics associated with each.
3. To understand some of the major innovations in arthropods. How do they solve the “problems” associated with exoskeletons: movement and growth?
4. To understand some reasons why arthropods (and insects in particular) are so diverse.

INTRODUCTION

Arthropods are by far the most diverse group of organisms on the planet (6-9 million species is a conservative estimate!). Currently, rRNA data suggest that this monophyletic group evolved from a **nematode-like** ancestor, potentially diversifying quickly during the Cambrian period (ca. 540 mya). Characteristics shared between arthropods and nematodes include the hormone **ecdysone**, which plays a role in **ecdysis** (shedding of the exoskeleton) in arthropods. Systematists had previously thought that arthropods evolved from an annelid-like ancestor (polychaete-like) because both of these groups are highly segmented, and, in both groups, **tagmosis** has occurred. **Tagmata** are types of segments associated with different regions of the body. This means that segment types have specialized functions. Sometimes the tagmata fuse into distinct regions (e.g., head, thorax, abdomen)—this process is called tagmosis (Figure 2).

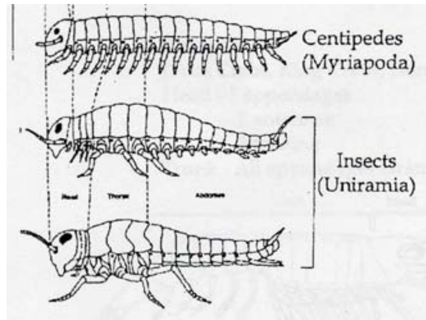

Fig 2.

The arthropods all have **exoskeletons** made of **chitin**. The exoskeleton provides these animals with support, holding muscles and tissues in place, and providing attachments for muscles. Exoskeletons also provide protection—the exoskeleton is often very hard, providing arthropods with "body armor". With the evolutionary innovation of the exoskeleton came selection pressure for characteristics that solve the potential problems of "life in a box": movement and growth.

Movement:

Arthropod exoskeletons are produced in segments, corresponding with segments (or tagmata) of their bodies. In between these plates of exoskeleton are **joints** that allow for a huge range of motion. In addition, each segment is usually associated with one set of appendages. These appendages are also jointed, which is unique among the invertebrates, and gives the arthropods their name, "jointed legs". Appendages are moved through the use of muscles that attach to the exoskeleton. Because arthropods completely lack cilia and flagella (except for sperm), they must generate water currents, swim, walk, jump, feed, dig, etc., using these muscular, jointed appendages. Arthropods are extremely diverse in their body sizes and shapes, and are likewise incredibly diverse in the shapes, sizes, and functions of their appendages. In addition, these appendages can be branched at the base, or **biramous**. Appendages that do not branch at the base are called **uniramous** appendages (Figure 3).

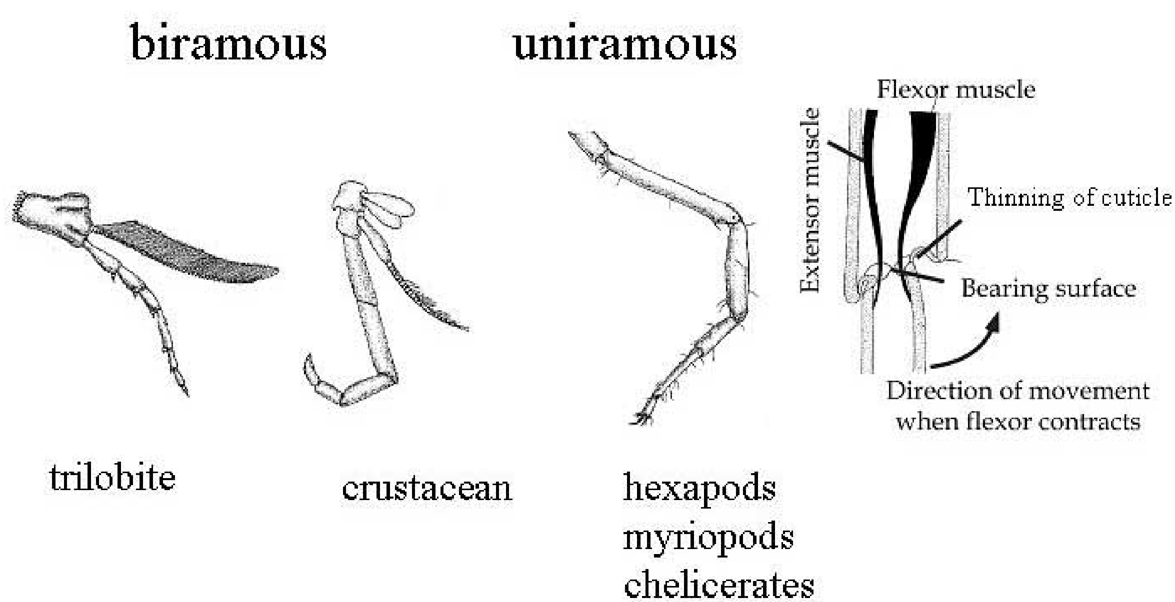

Fig 3.

Growth:

Arthropods grow in stages. They shed their old, smaller exoskeletons periodically, first secreting a new, soft exoskeleton underneath. After emerging from their old exoskeleton, the new one is inflated (with water or air) to a larger size before it hardens. This process is called **ecdysis**, or **molting**. What are potential problems with this method of growth?

Circulation and respiration:

Arthropods do have a coelom (a reduced one), which is used as part of their circulatory system. Arthropods take in O_2 and release CO_2 through organs (gills or lungs) that are either branched or in flat sheets (**why**?)—these organs vary in form among arthropod subphyla (Figure 4). Body movements of arthropods often aid in circulation and respiration.

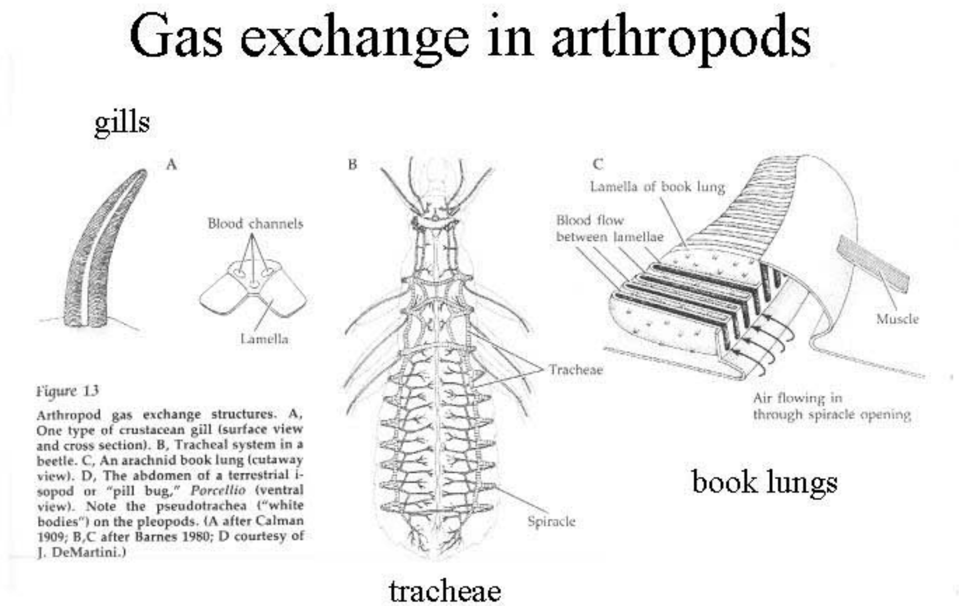

Fig 4.

As you go through the lab, use the chart below to help you organize some of the information in the lab on the major subphyla of arthropods.

	Appendages (biramous or uniramous?)	**Main body regions** (# and type)	**Organs used for respiration**	**Relative numbers of walking legs**	**Type of eyes** (compound or simple?)
Trilobites					
Myriopoda					
Chelicerata					
Crustacea					
Hexapoda					

I. TRILOBITES

This extinct subphylum was incredibly diverse in the Cambrian period. Observe the fossils and the replicas on display. Draw a couple of specimens in the spaces provided below. Pay close attention to their appendages—what type of appendages do they have? Do they have compound or simple eyes? **They have biramous appendages and compound eyes**

→

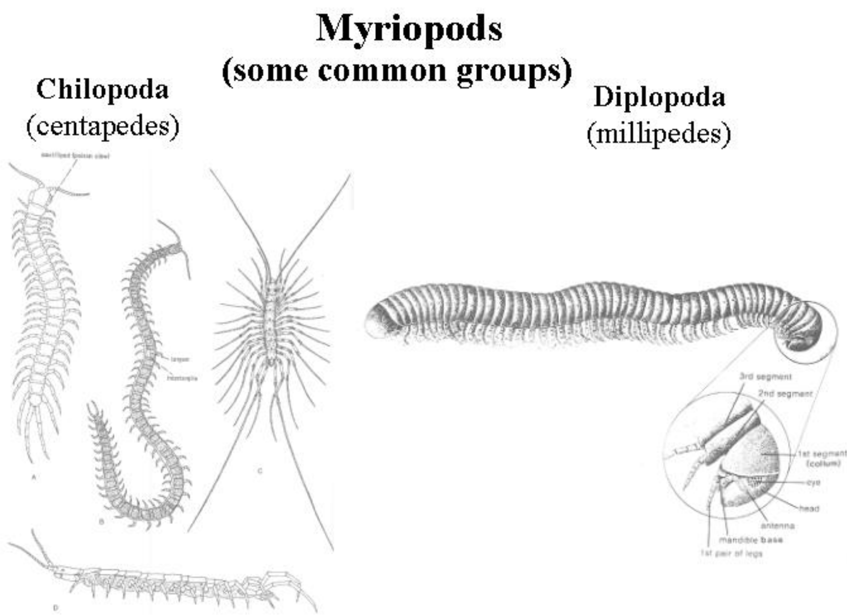

Figure 5.

II. MYRIOPODA

Several arthropod groups have invaded the land. This group is primarily terrestrial. In what ways is the arthropod exoskeleton "pre-adapted" for life on land? What other types of adaptations might be necessary for successful life on land?

Preadaptation—support against pull of gravity—organism does not collapse. Other adaptations include a waxy cuticle outside exoskeleton, etc.

→ Observe the centipedes (class Chilopoda) and millipedes (class Diplopoda) on display. How are their walking appendages arranged? In millipedes, pairs of segments actually fuse—how does this change the arrangement of their walking appendages?

In millipedes, fused pairs of segments result in two pairs of legs per fused segment…

→ Based upon your observations of movement (if live specimens are available) and mouthparts (on preserved specimens), what do you suppose are the primary feeding habits of each of these groups?

Millipedes are slower moving (herbivorous, unlike the predacious Chilopoda), also built for burrowing into soil/under logs (fused segments are good for this).

Members of both groups produce potent poisons. Given what you know about how members of these groups feed, why might poisons be useful in Chilopods? In Diplopods?

Chilopods: venom for subduing prey **Diplopods: defense against predators**

Chelicerates

(some common groups)

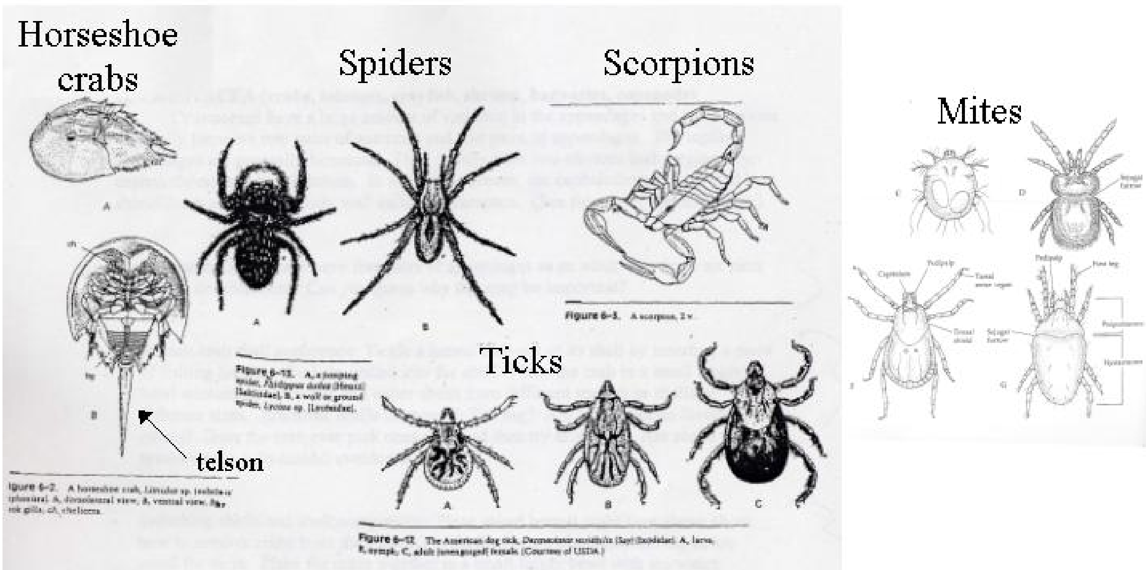

Figure 6.

III. CHELICERATA

This group is also primarily terrestrial, although pyncnogonids (sea spiders) and merostomates (horseshoe crabs) occur in salt water. Chelicerates have two main body regions: cephalothorax (no clearly separate head) and abdomen. They typically have six pairs of appendages: one pair of appendages used for feeding (called **chelicerae**), one pair of appendages used for sensory purposes (called **palps**), and four pairs of walking legs. This varies somewhat among groups, as do the shapes and sizes of these appendages. As you look at specimens of the different groups, make sure you can identify the chelicerae, the palps (especially in spiders), and the walking legs. For respiration, chelicerates use **book lungs**—or **book gills**, in aquatic chelicerates (Figure 3).

→ Observe the preserved specimens of scorpions, and the preserved spiders (and the live tarantulas!). Find chelicerae, etc. In tarantulas, where are their palps (in this case, called **pedipalps**)? In amblopigids (tail-less whip scorpions), how are their chelicerae and palps modified? For what purposes ?

Palps may be modified for walking legs, sensory purposes, raptorial (predatory) limbs, etc.

→ Horseshoe crabs (*Limulus* sp.) are chelicerates! Which end is the front end (look carefully before you decide)? Find their eyes—are they compound or simple? Find their chelicerae, and the **gnathobases**, spiny extensions of the bases of their appendages. For what purpose do you think horseshoe crabs use these? How do horseshoe crabs breathe (find the organs they use for this)? **Book gills.** What might be the pupose of the spine-like **telson**?

Gnathobases are for Grinding up food. Use book gills. The telson is for righting itself when on its back.

Some chelicerates, including some scorpions and some spiders (wolf spiders) exhibit some form of parental care—carrying newly-hatched babies on their backs for a while. What are some possible advantages of this behavior? Some possible disadvantages?

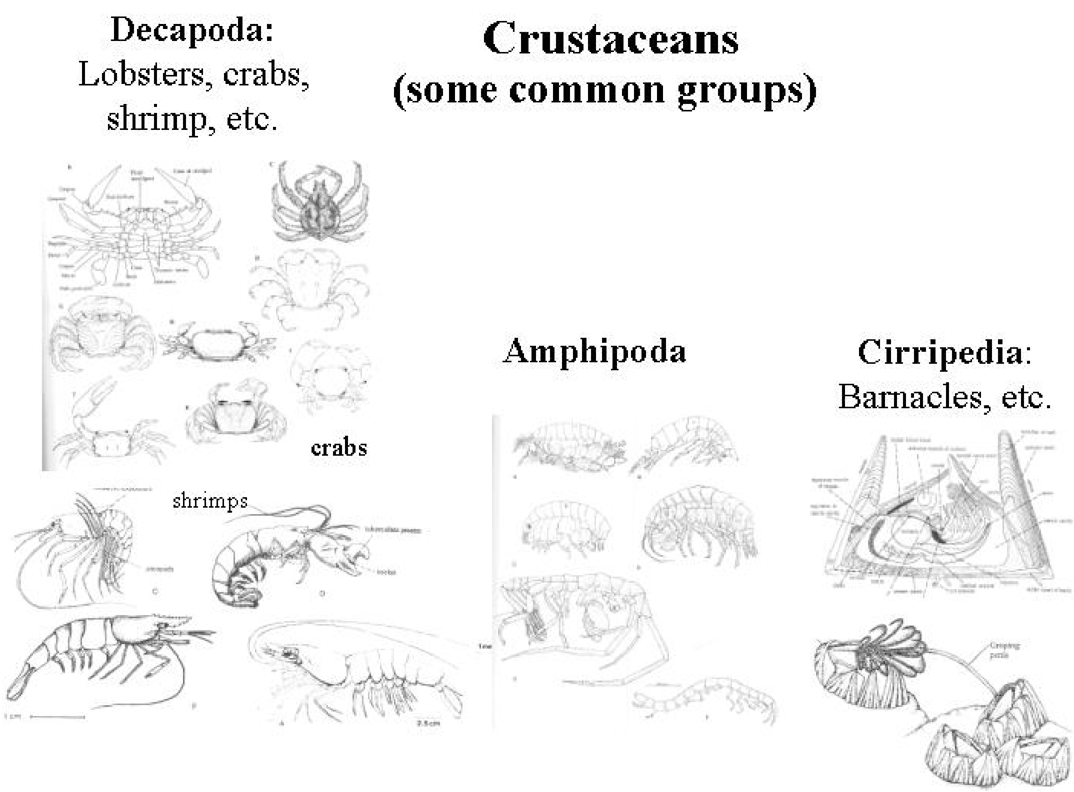

Figure 7.

IV. CRUSTACEA

Crustaceans are primarily aquatic, although some have secondarily invaded the land. They vary trememdously in the shapes and sizes of their appendages and body regions. Typically crustaceans have two pairs of antennae and five pairs of appendages (at least in the Decapoda, which includes shrimp, crabs, and lobsters). The leg-like appendages are generally biramous. Crustaceans usually have two main body regions: the cephalothorax (a combination of "head" and "thorax") and the abdomen. Crustaceans often have a planktonic larval stage. What are the main function(s) of this stage in the crustacean life cycle? What are the main function(s) of the adult stage?

Larval stage for dispersal (and feeding), Adult stage for reproduction and feeding/growing.

→

Observe the crustaceans on your table. Construct a dichotomous key, using the instructions provided by your TA, for the following five groups of crustaceans (in containers on your tables): Amphipoda, Isopoda, Branchiopoda (*Daphnia*, a cladoceran), Copepoda, and Ostracoda.

→ Observe the crayfish. Draw it, labeling the cephalothorax and abdomen. Where is the carapace (the shield-like plate of exoskeleton covering the cephalothorax (and sometimes part of the abdomen)? How many antennae do they have? **Two pairs.**

Crayfish	antennae

→ Open up your crayfish, and carefully remove some of the appendages of the head region of the cephalothorax, the thoracic region of the cephalothorax, and the abdomen (**make sure to remove them from the base**!). Are these appendages **biramous** or uniramous?

Where are their gills (**they branch from the base of the appendages**)?

For what purposes do the crayfish use different types of appendages?

Draw some appendages from each body region, and make notes about some of the morphological adaptations of appendages used for different purposes. Use one of the walking legs to demonstrate how these animals get a full range of motion from their jointed appendages.

Drawings of some appendages

→ Observe the variety of crustaceans on display (in tanks on your tables, and the back tables). These include many decapods, brine shrimp, and Barnacles (Cirripedia). Barnacles are sessile as adults. What is the advantage of the $CaCO_3$ plates they secrete (why are they especially useful, given their lifestyle)(**protection**)? How do these animals feed? **Their legs draw in food particles. You could mention a parasitic barnacle that lives inside crabs and behaves like a fungus.**

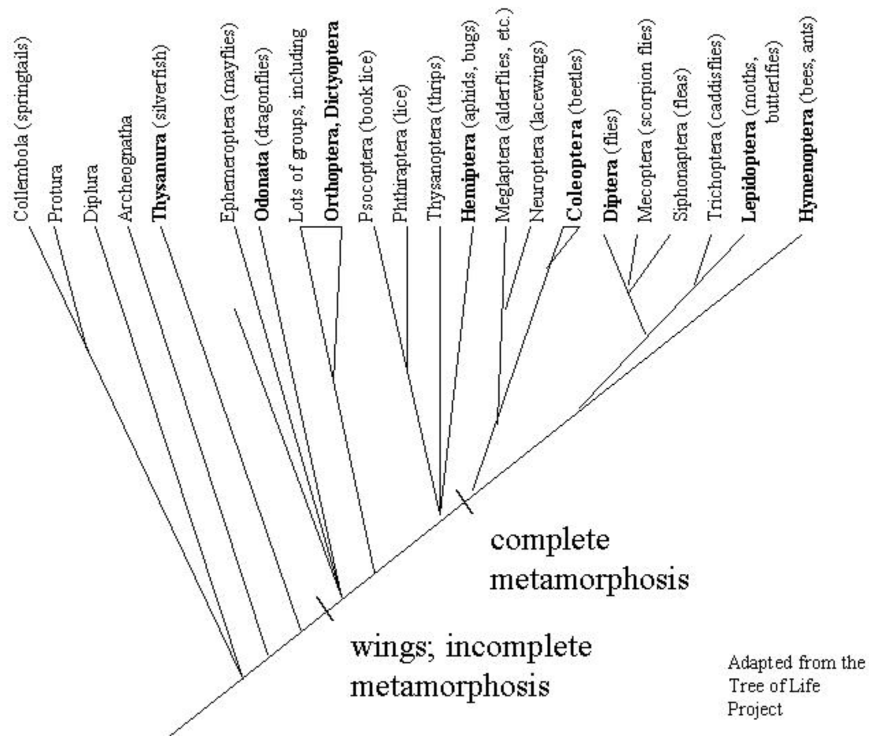

Figure 8. Phylogeny of the Hexapoda, with groups present in lab in **bold**.

V. HEXAPODA (collembolans, diplurans, proturans, and insects):

This is by far the most diverse subphylum of the Arthropoda. The Hexapoda are generally known as insects, although some scientists exclude the orders Protura, Collembola, and Diplura from the class Insecta. Their bodies are arranged into three distinct regions: head, thorax, and abdomen. They have one pair of antennae and several pairs of feeding appendages (including mandibles and maxillae) on the head. This group is named for their three pairs of uniramous walking appendages, one pair for each thoracic segment. Hexapods are mostly terrestrial, although some have secondarily invaded aquatic environments. Hexapod exoskeletons have an additional thick, waxy coating on exoskeleton (**cuticle**) that protects them from desiccation. Hexapods respire through branched **trachea** (from holes called **spiracles** on their lateral thorax and abdomen), which carry O_2 directly to muscles. Most insects have two pairs of *wings* that are **not** derived from pre-existing appendages. They copulate and inseminate directly, often after elaborate courtship. Females can sometimes store sperm for long periods. There are generally no appendages on the abdomen, but externally visible reproductive organs may be present. These are the morphological features, but several other key features have helped make this group so incredibly diverse—following is an exploration of some of these features.

→ Examine the mouthparts of the preserved crickets (mandibles and maxillae)—how are these appendages modified?

Find the spiracles on the sides of their abdomen.

Life cycles and Metamorphosis

Insects have three main types of life cycles.

1. **Ametabolous**—larvae look like small adults (neither have wings), becoming progressively larger with each molt, while remaining very similar morphologically. Larvae usually live in the same habitats and share the same feeding habits, etc., as adults.

→ Example: Observe specimens of Thysanura (silverfish—*Lepisma* sp.).

2. **Hemimetabolous**, or **incomplete metamorphosis** (figure 8)—larvae (called **nymphs**) usually share eating habits of adults, but sometimes live in different habitats. Larvae look progressively more like adults with each molt, but only adults have wings.

→ Examples: Examine live and mounted specimens of Odonata (dragonflies), Orthoptera (grasshoppers and katydids), and Hemiptera (true bugs, aphids, etc.). What are some possible advantages of aquatic nymphs and terrestrial adults in odonates? Some possible disadvantages? How do Hemipteran mouthparts function?

Using separate habitats—less competition between life stages. But adults need to find the correct, different habitat for laying eggs, etc. Hemipteran mouthparts are "piercing-sucking"—they pierce into plants or animals and suck phloem or guts, respectively.

3. **Holometabolous,** or **complete metamorphosis** (figure 8)—larvae usually look very different from adults, often living in different habitats and feeding in very different ways than adults. This life cycle contains a separate life stage called the **pupa**, in which the larval-like form undergoes **metamorphosis**—the process of transforming into the adult form. Larvae contain clusters of cells called **imaginal discs** that will differentiate into morphological features of adults (wings, adult mouth parts, etc.) during the pupal life stage.

→ Examples: Examine live and mounted specimens of Coleoptera (beeltes), Diptera (flies), Lepidoptera (moths and butterflies), and Hymenoptera (bees, wasps, and ants).

Metamorphosis is a key innovation in the insects. Think about the following questions as you examine the live and preserved specimens on display:

What are some advantages of the hemimetabolous and holometabolous life cycles?
Some outlined above.

How might these advantages lead to greater diversity?
Greater possibilities for niche variation/habitat specialization, and selection can act separately on different parts of the life cycle.

What are some disadvantages of these life cycles (especially holometabolous)?
Problems with the pupal stage (very vulnerable to predators), greater chance for malfunctions in development.

What function does the larval stage serve in the life cycle of these insects?
Feeding and growth.

What function does the adult stage serve (how is this different from the Crustacea)?
Reproduction and dispersal (sometimes feeding too)—in some ways, opposite of Crustaceans.

Insect flight

Most hemimetabolous and holometabolous insects have two pairs of wings (the ones that don't have lost theirs—winglessness is a derived condition). Wings are not modified appendages, but rather extensions of the chitinous exoskeleton found on the thorax. There are three main theories of how insect wings may have evolved.

1. *Thermoregulation:* insects are ectothermic, and therefore must rely on their surrounding environment to heat up their bodies. Wings may be a way for insects to catch more light to heat up their bodies. Eventually these were co-opted as instruments for flight.
2. *Protection:* wings may have been used for insects to jump away from predators and glide down to the ground. They also may have stabilized jumping insects. Eventually muscles evolved that moved these chitinous extensions, and they became wings.
3. *Gill flap theory:* wings may have evolved from aquatic insects that used them to row themselves through the water or ventilate their gills. Once they moved to land, they were co-opted for flight.

→ Examine the wings of various insects. Wings may serve many functions in addition to flight. What are the functions of each pair of wings in Orthoptera (katydids)? Coleoptera? Lepidoptera? Diptera (this is tricky—look at a specimen under the dissecting scope)?

Orthoptera (katydids): First pair for camouflage, and the second for flight.

Coleoptera: First pair for defense (hard parts), and sometimes camouflage or advertisements of poisons inside; the second pair for flight.

Lepidoptera: Both pairs for flight, but sometimes there are specialized wing scales used in chemical communication.

Diptera. First pair is for flight, and second pair is modified into halteres that work as gyroscopes to stabilize the flies for hovering.

Sensory Organs

Insects use chemical, visual, and sometimes audio cues for communication—their range of sensory capabilities is tremendous, especially chemical communication, which is very diverse in form and function, and can be incredibly complex. Antennae are some of the main chemoreceptors of insects, enabling them to “taste” the air or other objects they touch. Some antennae are very intricate structures that can pick up small amounts of chemicals. Some examples include **pheremones**—chemicals released to communicate with members of the same species, and **kairomones**—chemicals released by members of one species to communicate with members of other species. Insects also have small hairs (**setae**), some of which can sense movement and position of their bodies. Much like the whiskers on a cat, they can detect objects touching (or nearly touching) their bodies.

→ Look at the antennae of the moths on display. Male giant silk moths (family: Saturnidae) have antennae that look like feathers (highly branched). Given that in this family, adult moths do not feed, and female moths do not move much after emerging as adults, how do you suppose males find female Saturnid moths?

Branched antennae on males have lots of pheromone receptors—males fly to females, using pheremones released by females to navigate to them.

Insects may exhibit an array of light-sensing organs. Some have ocelli, organs that can only tell light from dark. Others have compound eyes, which are thousands of light receptors combined into a single pair of eye-like structures. Some have both types—you can see ocelli on grasshopper specimens, in between their two larger compound eyes. Most insects cannot see much in the red zone, but many insects can see UV light (and butterflies can see both).

→ Examine some insect eyes—take a look at them under a dissecting scope! Find ocelli on crickets, and compare them with the compound eyes (using a dissecting scope).

Compound eyes Ocelli

Some insects have hearing organs. Part of the cuticle is very thin, and can pick up vibrations. These vibrations are sent to the nervous system. Insects cannot hear tones (they cannot detect frequency differences), so they use temporal patterns instead.

Why might hearing be useful for crickets and katydids? For cicadas?
Location of mates!

Some moths can detect sound waves—why might this be advantageous to them?
Avoidance of bats.

Mimicry

Many insects have cryptic coloration, mimicking some aspects of their surroundings. What examples of this do you see on the mounted specimens? Why might it be advantageous for a katydid to look like a leaf (**hiding from predators**)? What might be a different reason why it might be advantageous for a praying mantis to look like a leaf (**ambushing prey**)?

Many insects mimic other insects that are poisonous—often with strong patterns of black and yellow, or bright red and black. Why might poinsonous insects be so bright (**advertising, so predators avoid eating them after a previous bad experience. Sometimes this is inherited behavior though—no previous experience needed.**)? How might some insects acquire their potent poisons (**feeding on plants with secondary chemistry, and incorporating these chemicals**)? In what life stage do they acquire them (**larval—occasionally adults acquire them later**)?

→ **Müllerian mimicry**—where both the mimic and the model are poisonous.

Examine the mounted monarch butterfly (*Danaus plexippus*) on display. This butterfly and the Viceroy (*Limenitis archippus*) are both poisonous—they mimic each other. In Florida, the monarch is less common than the related queen butterfly (*D. gillipus*), which is a much darker red. There, the wings of Viceroys are also a much darker red.

→ **Batesian mimicry**—where the mimic is not poisonous.

Examine the mounted specimens of Diptera, to find another example of mimcry. Why might this be advantageous? **Look like wasps—predators may avoid them if they think they might get stung.**

Sociality and parental care

Sociality evolved at least twice in the Insecta: Isoptera (termites) and Hymenoptera (in some bees, some wasps, and most ants). **Eusocial** (truly social, as opposed to colonial) insects have amazingly structured societies, often with **castes** (in termites, ants, and bees)—morphologically distinct types of individuals within a species that serve different functions. For instance, one caste may do little else besides reproduce (queens), others may harvest food for the group and help build nests (workers), and others may defend nests and workers (soldiers). What morphological modifications might you expect to see in "soldiers"? Members of different castes are often produced when larvae are fed different amounts, or when larvae are fed different foods. What might be some advantages of sociality in insects? Some disadvantages?

Possible advantage: Greater specialization/efficiency for food gathering, reproduction, etc. Possible disadvantage: if queen is dead, then colony is dead, etc.

You could mention ant slavery here—some ants can enslave other ant species.

Isoptera (within Dictyoptera, see Figure 8)

All termites are eusocial, with winged reproductives (kings and queens) and wingless soldiers and workers. Termites of any caste might be males or females. Examine lab colonies, if available.

Caste 1 (label)	Caste 2 (label)

Hymenoptera

Relatively few wasps and bees are social, and those that are have little caste differentiation. In wasps, workers all have the potential to reproduce. The queen is established by winning a dominance fight between egg-laying females. In bees, the queen is fed a special diet during development, called royal jelly. Females are usually workers, and reproducing males are called drones. In ants, males live for a short time, mating with the queen before they die. Only the queens reproduce, producing all-female offspring (workers and soldiers). When colonies get above a certain size, winged males and new winged queens are produced. What purpose does this serve?

Forms new colonies, dispersed elsewhere to reduce the possibility that local resources are outstripped.

These and many other insects exhibit some form of parental care—guarding eggs until they hatch, and/or carrying larvae/nymphs on their backs for a while. What are some possible advantages (and disadvantages) of parental care in social insects (over parental care in non-social insects)?

Plants revisited

As you have seen in previous labs, insects are closely associated with plants, especially the angiosperms. Plants are food for many insects, and often provide shelter as well (often unwittingly). Herbivorous insects can do tremendous damage to plants. Plants have evolved many chemical (**secondary plant compounds**) and mechanical (hairs called **trichomes**, etc.) defenses against herbivores, and some insects have evolved ways to get around these defenses (often this co-evolution is referred to as an "evolutionary arms race")—some insects are very closely tied to plants evolutionarily—some can only feed on plants that produce certain poisons.

→ Take another look at pollination syndromes, paying attention to morphological features of the insects involved. How might some bees collect pollen? **Pollen baskets—specialized hairs on one pair of legs.** Why do butterflies often prefer long tubular flowers? **Long, tubular proboscis.**

TEST YOURSELF

1. Can you distinguish and name each subphylum of Arthropods?
2. Can you name some of the morphological and behavioral traits associated with members of each (including some key innovations)?
3. How do different groups of arthropods solve problems associated with life in a box? How are the jointed appendages modified differently in each subphylum?
4. Can you name some reasons why arthropods, and insects in particular, are so diverse?

Dichotomous Key for a few groups of Crustaceans

A few times during this semester, we have used dichotomous keys to identify organisms we are studying. These keys can help us learn characteristics that can be used by field biologists to distinguish between groups of organisms. Construct a dichotomous key, using these five groups:

Amphipods
Isopods
Branchiopoda: Cladoceran (Daphnia)
Copepoda
Ostracods

To do this, first make careful observations of the characteristics of each organism, to determine which characteristics are shared, and which can be used to distinguish between organisms. Examples of important characteristics could include: numbers of legs, numbers of body segments, positions of legs, numbers of types of legs (do they all look the same?), body arrangement (flattened laterally—from side to side—or dorso-ventrally—from top to bottom). Second, make a chart of these characteristics (you may use the one below as a prototype)—keep going until you have a way to distinguish each group from each other group. Third, work on making your dichotomous key on the back of this sheet.

Characteristics (label these characteristics on the top row)

Amphipods									
Isopods									
Branchiopoda: *Daphnia*									
Copepoda									
Ostracods									