AMAZING ARTHROPODS!

2016 STUDY GUIDE

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NOT OFFICIAL EVENT RULES
Events will be judged by
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Table of Contents:

Summary of Exam Knowledge Needed:

List of Arthropod Classes that students will be required to recognize on sight, be familiar with the major groups included, their basic biology & anatomy (below are some suggested references, but similar information can be found on numerous websites, if any of these links are broken)**:**

- Arachnida (Spiders, Scorpions, Ticks, and relatives)
  http://www.biokids.umich.edu/critters/Arachnida/
  http://entomology.ucdavis.edu/Faculty/Robert_B_Kimsey/Kimsey_Research/Tick_Biology/
- Chilopoda (Centipedes)
  https://en.wikipedia.org/wiki/Centipede
- Collembola (Springtails)
  http://www.cals.ncsu.edu/course/ent425/library/compendium/collembola.html
- Diplopoda (Millipedes)
  https://en.wikipedia.org/wiki/Millipede
  http://www.earthlife.net/insects/diplopoda.html
- Insecta (Insects)
  http://biology.clc.uc.edu/courses/bio106/arthrpod.htm
- Malacostraca (Crabs, Crayfish, Isopods, Pill bugs, and relatives)
  https://en.wikipedia.org/wiki/Malacostraca

List of Insect Orders that students will be required to recognize and/or use a dichotomous key to identify and be able to recount basic biology, life history (type of metamorphosis), and ecology (habitat, diet) of:

- Blattodea (Cockroaches & Termites)
- Coleoptera (Beetles)
- Dermaptera (Earwigs)
- Diptera (Flies)
- Hemiptera (True bugs, Cicadas, Hoppers, and relatives)
- Hymenoptera (Ants, Bees, & Wasps)
- Lepidoptera (Butterflies, Moths, & Skippers)
- Mantodea (Mantises)
- Neuroptera (Antlions, Lacewings, and relatives)
- Orthoptera (Crickets, Grasshoppers, and Katydids)
- Odonata (Dragonflies and Damselflies)
- Siphonaptera (Fleas)

List of specific species, or closely related groups of species, that students must be able to visually recognize and recount the taxonomy (what Class/Order they belong to), life history, ecology, and economic impact (how do they help or harm humans), or conservation status:*

- American Burying Beetle (*Nicrophorus americanus)*
- Antlion (*Myrmeleon immaculatus*)
- Black-legged Tick (*Ixodes scapularis*)
- Bumble Bees (*Bombus* spp.)

- Eastern Carpenter Ant (*Camponotus pennsylvanicus*)
- Eastern Subterranean Termite (*Reticulitermes flavipes*)
- German cockroach (*Blattella germanica*)
- Gypsy Moth (*Lymantria dispar*)
- Hine's emerald dragonfly (*Somatochlora hineana)*
- Honey Bee (*Apis mellifera*)
- Human Bed Bug (*Cimex lectularius*)
- Japanese Beetle (*Popillia japonica*)
- Karner Blue Butterfly (*Lycaeides melissa samuelis)*
- Leadplant moth (*Schinia lucens)*
- Multicolored Asian Lady Beetle (*Harmonia axyridis*)
- Paper Wasps (*Polistes* spp.)
- Pavement Ant (*Tetramorium* sp.)
- Yellow Jackets (*Vespula* and *Dolichovespula* spp.)

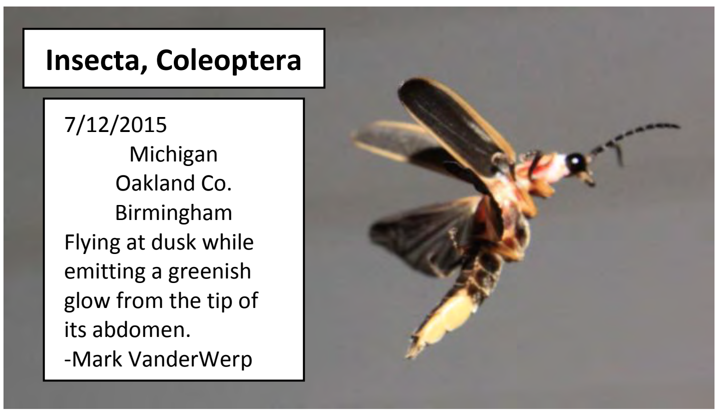
List of specific Concepts to Study

- Linnaean Classification
  http://study.com/academy/lesson/carolus-linnaeus-classification-taxonomy-contributions-to-biology.html
- Basic Arthropod Anatomy (major body parts, appendages, what they're used for)
  https://iweb.tntech.edu/cabrown/entomology/externalanatomy3330.pdf
- How to use Identification Keys (practice helps!) (see provided event pdf for Class ID)
  An easy to use key to insect orders: http://www.knowyourinsects.org/index.html
- Various methods of collecting arthropods and what specific tools/equipment are used in various habitats (see provided event pdf)
- Insect Growth & Metamorphosis (see provided event pdf)
- Insect Defenses
  http://www.cals.ncsu.edu/course/ent425/library/tutorials/ecology/defenses.html
- Insect Respiration
  http://www.cals.ncsu.edu/course/ent425/library/tutorials/internal_anatomy/respiratory.html
- Economic Impacts
  http://www.cals.ncsu.edu/course/ent425/library/tutorials/importance_of_insects/impact_of_insects.html
- Pest Control Tactics
  http://www.cals.ncsu.edu/course/ent425/library/tutorials/applied_entomology/control_tactics.html (also follow the link at the bottom of the page for info on "Cultural control", "Biological control", "Physical & Mechanical control", and "Semiochemicals")

Arthropod Specimen/Photography Collection Rules

You must make an arthropod collection, but may choose to use actual pinned specimens (see handout #5) **OR** by photographing specimens (preferably when alive). The following apply to both collection types:

- All specimens should be **adults** (no caterpillars, maggots, or other immatures), **local** in origin (from the Midwestern U.S.), and collected or photographed **within a year** of the Science Olympiad competition date by the team members.
- All specimens/photos must bear collection data, associated with each individual specimen. It should be on a paper card below pinned specimens and as a digital insert on or immediately below a photo, see examples below. Labels must consist of the following data:
    1. Date collected
    2. Location collected (State, County, & nearest City)
    3. Brief behavior/habits observed during collection. *For instance, you could say it was eating a leaf, or swimming in a pond.*
    4. Name of collector (this should only be you or your teammate!)



- All specimens should be identified to Class. Then all specimens in Class Insecta should be identified to Order. Specimens should be grouped by Class first, then sub-grouped by Order (insects only). No further identification below this level is needed for this event.

The following rules pertain only to <u>Pinned Specimen Collections</u>:

- Collections should be housed in a sturdy cardboard or wooden box with a lid, not to exceed 16.5" x 19" (this size is called a "Cornell box"). Styrofoam or similarly porous and flexible material should be placed on the bottom for the pins to stick into. Professional insect drawers may be purchased (see sources below), but are not required.
- Freezers are your friend! Insects can be placed in a bag or container and placed in a freezer for a couple of days to kill the specimen before mounting (you'll want to thaw specimens before mounting or they may crack). *Be sure to check with an adult before putting bugs in the freezer!*
- Insect pins, for mounting specimens, can be obtained from any number of biological/entomological supply stores. **Professional insect pins must be used** as they work much better than sowing pins for insect collections. They come in multiple sizes, but a size #2 is appropriate for general use and should be the only size needed for this project. Here is the main insect pin supplier to consider:

Indigo Instruments
www.indigoinstruments.com

The following rules pertain only to Photographic Collections:

- The collection should be housed in a photo album or combined onto a poster (not to exceed 24"x36") or otherwise professionally put together. *For instance*, a *bunch of printed pictures paper clipped together is NOT acceptable.*
- In the collection you must describe what camera you used to take the pictures and what lenses you used (if you are using a camera body that can accept multiple lenses or aftermarket lenses designed to fit over equipment like a mobile phone). If you use a number of cameras/lenses list them all.
- Photos must be in focus and allow for proper identification of the specimen, which means they must show necessary features, like number of legs, wings, etc (based on info needed in the identification keys). Blurry images or photos taken from too far away will not be counted.

ACCEPTABLE

NOT Acceptable

- Freezers are your friend! You may want to pop a very active specimen (or one prone to flying away from you) into a freezer for 1-5 minutes to chill it before returning it to its habitat, allowing for better pictures to be taken. *Don't worry they will recover!*
- If you have multiple images of the same specimen and no single shot is adequate for identification you may use multiple images in your collection. If multiple images of the same specimen are used please clearly indicate this, and of course, these multiple images will only count for one specimen! *For instance, if you need to see the head and number of wings to make a proper identification and you have 2 photos one with the head in focus and one with the wings in focus, you may use both images to count for one specimen.*
- Images should be cropped to emphasize the subject and not include a lot of blank space or unnecessary background.
- Photos must be of only one specimen! *For instance, a picture of a spider with a fly in its web does* ***NOT*** *count for two specimens. But it would be a welcome image demonstrating what a spider does ecologically!*

Taxonomy of the Phylum Arthropoda

Subphylum Chelicerata (kuh-lis-er-a-da)

- Class Arachnida (uh-rak-ni-da) - Spiders, Harvestmen, Scorpions, Ticks, and others
- Class Merostomata - Horseshoe Crabs
- Class Pycnogonida - Sea Spiders

Subphylum Crustacea (kruh-stey-she-a)

- Class Branchiopoda
- Class Malacostraca (mal-uh-kos-truh-kuh)- Crabs, Crayfish, Isopods, and others
- Class Maxillopoda
- Class Ostracods

Subphylum Hexapoda (hex-ah-po-da)

- Class Insecta (in-sek-ta) - Insects
- Class Diplura - Bristletails
- Class Protura - Coneheads
- Class Collembola (kuh-lem-buh-luh) - Springtails

Subphylum Myriapoda (mir-ee-uh-po-da)

- Class Chilopoda (ky-luh-po-da) - Centipedes
- Class Diplopoda (dip-luh-po-da) - Millipedes
- Class Symphyla
- Class Pauropoda

Example of Linnaean Classification:

Kingdom	Animalia
Phylum	Arthropoda
Class	Insecta
Order	Coleoptera
Family	Tenebrionidae
Genus	*Alphitobius*
Species	*diaperinus*

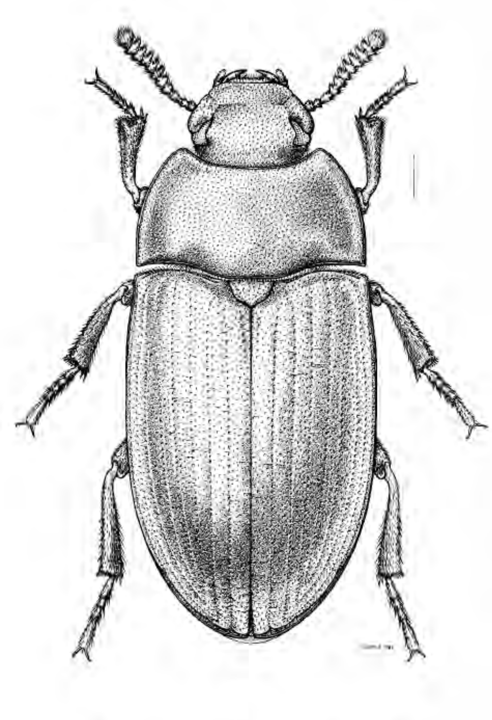


Fig. 231 *Alphitobius diaperinus* (Panzer). Scale = 0.5 mm.

Classes highlighted in green are the only ones that students will be responsible to know for this event.

Using Identification Keys

The following passage on properly using keys is taken from the Encyclopedia of Entomology:

"Keys are arrangements of taxa (a group of organisms that is sufficiently different from other groups to be considered a unique group), with similar taxa—usually based on external morphology, or appearance—clustered together. Thus, insects with wings may be in one cluster, wingless in another. Then within one of these clusters, some other character such as antenna length is used to segregate individuals further: those with wings and long antennae in one cluster, those with wings and short antennae in another. Extended far enough, this process can lead to species-level determinations. Keys usually require the user to make a choice between only two characters at a time: so-called "dichotomous keys." However, it is also possible to have keys where the user is asked to pick among several groups of characters simultaneously. The choices are usually numbered (e.g., 1 and 1´, 2 and 2´, etc.), and the user is referred to various sections of the key by number.

In almost all cases, keys begin with a large taxon (e.g., arthropods or insects), and work down to smaller and smaller groups. Often insect keys segregate Orders, and then there are separate keys for each Order that separate Families, then other keys to distinguish among the Genera in the Families, and then finally keys to species, which sometimes are integrated with keys to the Genera. A common, but incorrect, assumption is that Order or Family keys are easier to use than species keys. The opposite is true. Keys to larger taxa must accommodate a great deal of variation, and sometimes it is difficult to find unifying characteristics.

Keys are often based primarily or exclusively on text: written description of a contrasting character or characters is used to distinguish among specimens. Illustrated keys have a major advantage in that they graphically display the characters of interest. It is much easier to understand differences among contrasting characters when they are illustrated. It also helps to have the key graphically displayed in a flow-chart arrangement. This gives the user better opportunity to see at a glance where the key is headed, and to easily work backward if diagnosis proves difficult. A few pointers on use of keys follow:

- Do not attempt to skip through a key, or to take short-cuts. Start at the beginning and work through the key methodically.
- Read the descriptions *carefully*; a large percentage of errors are caused by careless reading, or by the user not understanding the meaning of the words. Terminology may differ between taxa, so if you are not familiar with a taxon it is advisable to look up the exact meaning of terms. Illustrations are immensely helpful.
- You will be asked to make a series of decisions, usually making the "best" choice among two options. Your specimen should fit one of the two choices; if not, perhaps you made an incorrect decision earlier in the key.

- If more than one character is provided for you to examine, the first character is usually the most important. The others are secondary, or apply only in part.
- It is helpful to examine more than one specimen. It may be difficult to see a key character on certain individuals, or there may be sexual differences in the degree of expression.
- When you arrive at a final destination, do not automatically accept it. Always seek a more complete description of the organism to ascertain that the specimen seems to match.

Once you have determined the Order, the next step is to determine the Family within that Order to which the insect belongs. This may mean an increase in complexity, and will usually require additional knowledge about specific types of structures and the variation that exists within these structures. Once the Family of an insect has been determined you are left to hunt for literature that will permit identification to Genus and species. Not only may this prove difficult, it may prove impossible. Not all insects are discussed or are identifiable to species. Literature may be scattered, outdated, or non-existent. You may have to call upon specialists for help. This is a normal part of the identification process. For our purposes here we will concentrate upon keys that should help you arrive at a Class or Order level identification."

Reference:

Capinera, John. Encyclopedia of Entomology. Netherlands: Springer 2008. Print.

Key to Common Terrestrial Adult Arthropods *

1. Adult arthropod specimen

a) Specimen does NOT have antennae or wings AND has 8 legs plus one pair of leg-like or claw-like appendages (pedipalps)..Class Arachnida

b) Specimen has one or more pair(s) of antennae, legs variable ....go to **step 2**

2. Specimen with antennae

a) Specimen has six legs (may have other tails, spines, or appendages not primarily used for walking)..go to **step 3**

b) Specimen has more than six legs ....go to **step 4**

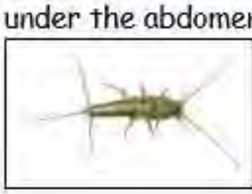
  

3. Specimen with six legs

a) Tiny specimens (0.5 - 6 millimeters long), never with wings, always with a cylindrical specialized organ (collophore) on the underside near the hind legs, and often have a flexible organ (furcula) used for jumping..Class Collembola

b) Size variable (1 mm - 4 inches long), may have wings, tails, or other abdominal protrusions, but never with a specialized jumping organ or cylindrical collophore under the abdomen. ....Class Insecta

* Make sure that specimen is in good condition, any broken or missing legs, wings, or antennae may invalidate your identification.

Key to Common Terrestrial Adult Arthropods (cont.) *

4. Specimen with more than six legs

a) Specimen has fewer than 9 pairs of legs and has an abdomen......**Class Malacostraca**

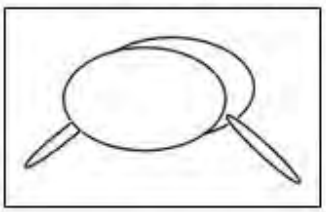
  

b) Specimen has 9 or more pairs of legs and no abdomen..................go to **step 5**

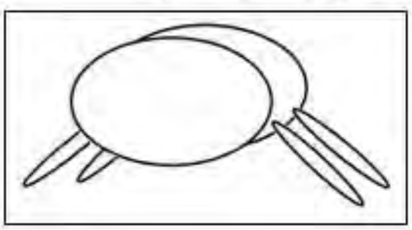
 

5. Specimen with 9 or more pairs of legs and no abdomen

a) Specimen has 1 pair (2 legs) per body segment................................**Class Chilopoda**

b) Specimen has 2 pairs (4 legs) per body segment.............................**Class Diplopoda**

* Make sure that specimen is in good condition, any broken or missing legs, wings, or antennae may invalidate your identification.

Arthropod Growth & Metamorphosis

All arthropod development is comprised of three major phases: **egg**, **immature**, and **adult**. That's right, all of these creatures start life off as an immobile egg which hatches (**ecloses**) into a very small immature form. When an arthropod first leaves the egg it is called a **first instar**, this stage is generally quite active and able to fend for itself but rarely seen because of its small size. To help keep the various types of metamorphosis distinct, different terminology is used for the immature stage; see if you can spot the 4 different terms for immature stages in the figures below (but they are all referred to generically as first instars).

The first instar will take in nutrients by eating and beginning to grow. However, as all arthropods have their "skeletons" (hard parts of their body) on the outside and their muscles and other soft tissues inside they must **molt** before growing any larger and entering the second instar stage. The hard outer covering of arthropods is known as the **exoskeleton**, which must be broken down and partially dissolved so that the first instar can break through it when molting. While the old exoskeleton is breaking down underneath it the new, and larger, one is forming inside. For anyone familiar with Russian nesting dolls, or Matryoshka dolls, you know that you can't put a larger doll inside of a smaller one, but that's essentially what arthropods are doing when they molt! This is possible as the new exoskeleton of the second instar hasn't fully hardened yet when emerging from the molted skin of the first instar. Often newly emerged arthropods are confused as being albino individuals as many appear as a very light whitish color. Once they crawl out of their old skin they will expand slightly before the new exoskeleton hardens and again takes on its characteristic darker coloration. The visible molting process is known as **ecdysis** and is usually complete within a few hours or less. This same process will repeat as the arthropods grows larger and larger, all of these instars taken together are known as the immature stage.

Fig. 1: Matryoshka dolls

Fig. 2: A cockroach undergoing ecdysis

Eventually the arthropod is a full grown adult that is capable of reproduction, i.e. mating, and if it's a female, laying eggs of its own to start the **lifecycle** over again. Adults often have features slightly or drastically different from the immature stages, this is where the term metamorphosis comes into play.

The term, **metamorphosis**, when used in biology describes how an arthropod (usually only used when discussing an insect) develops and what morphological, or anatomical, changes it undergoes while maturing. The word comes from the Greek roots "meta" and "morphe," which literally mean a changing of form. Metamorphosis is often described in slightly different ways and by using differing numbers of categories depending on the author. Here we will use the following four categories: **Without**, **Gradual**, **Incomplete**, and **Complete** metamorphosis.

Developing **Without metamorphosis** looks a lot like what it sounds like, there are no drastic changes from the first instar to the adult! The only difference is that the adult stage is larger and sexually mature, otherwise it looks just like an immature. Some arthropods in this group actually continue to grow and molt even after they've reached the adult stage!

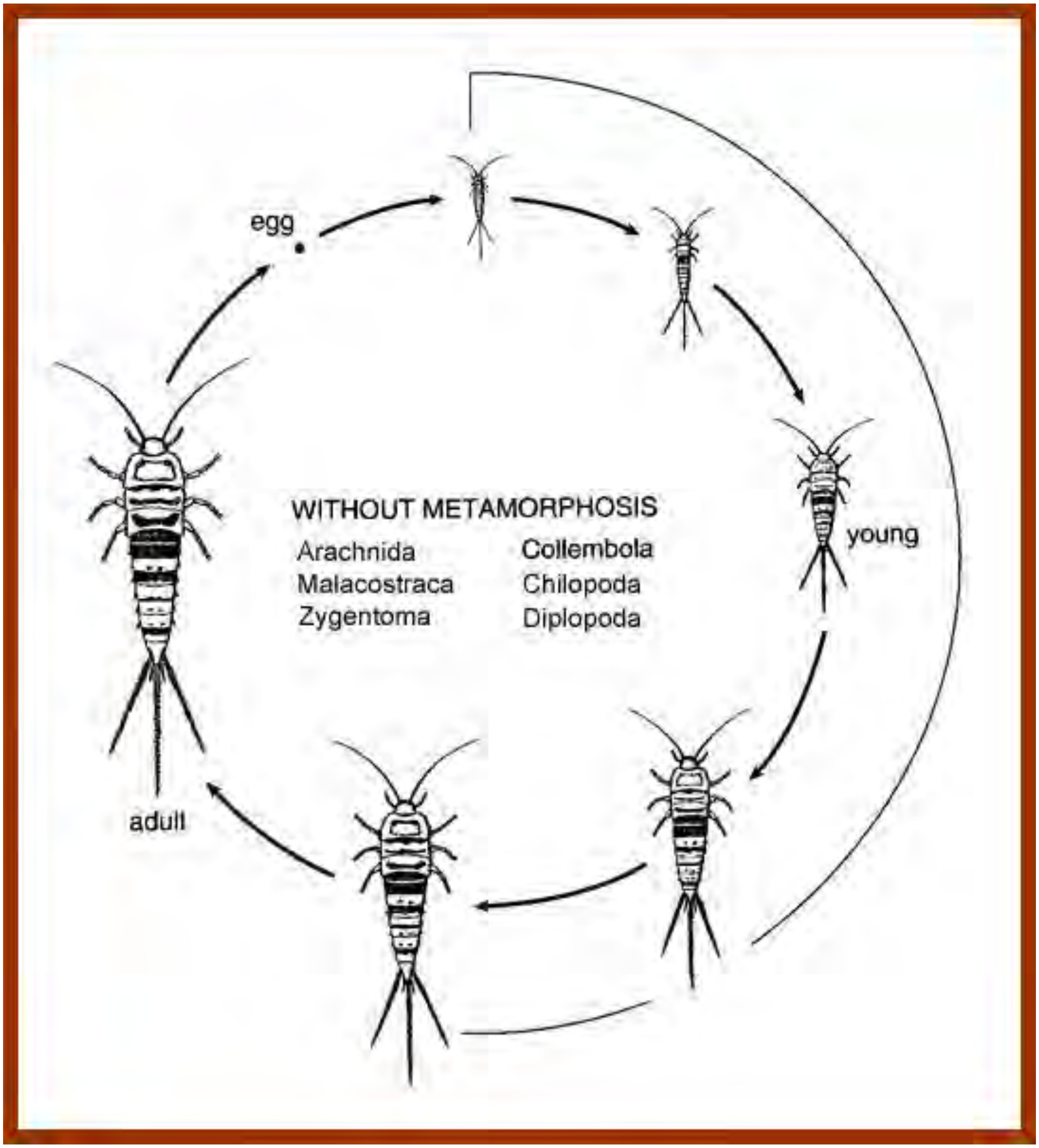


Fig. 3: A lifecycle diagram of a silverfish, which develops Without Metamorphosis

Gradual metamorphosis looks very similar to developing without metamorphosis, in that the nymphs and the adults very strongly resemble each other. However, adults are clearly different from the nymphs as they have fully developed wings (in species that are winged) in addition to being sexually mature. Species that undergo gradual metamorphosis are very common in the environment and undoubtedly having winged adults helps a species to move into new areas and find a wide array of food resources.

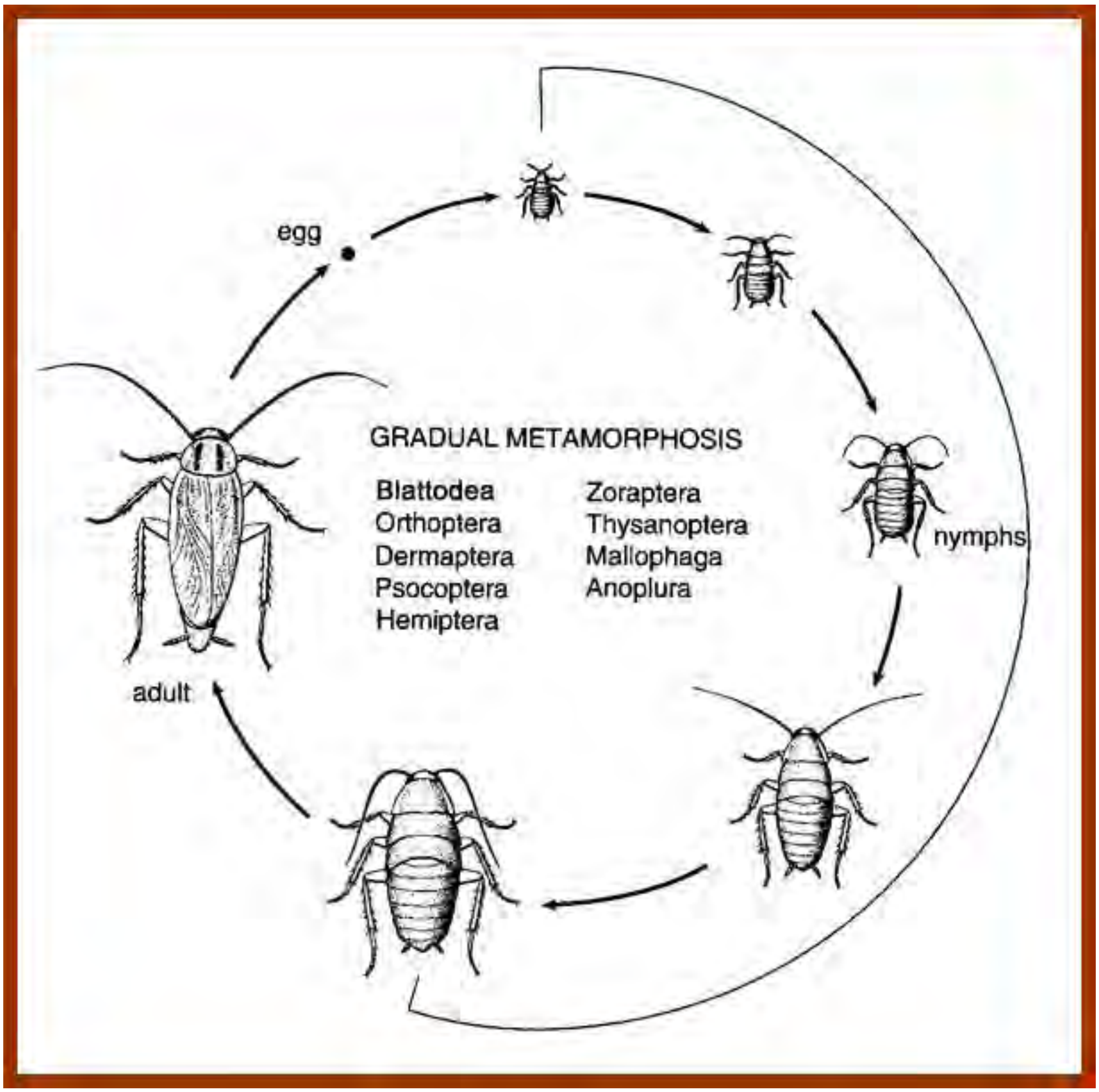


Fig. 4: A lifecycle diagram of a cockroach, which develops by Gradual Metamorphosis

Incomplete metamorphosis is where things start to get really interesting. All insect Orders that mature in this manner are aquatic species when immature and they do NOT resemble the adult forms. This is truly a transformation! The adults and immatures do not even inhabit the same environment! The aquatic naiad must crawl out of the water or float to the surface in order for the winged adult to emerge and fly away.

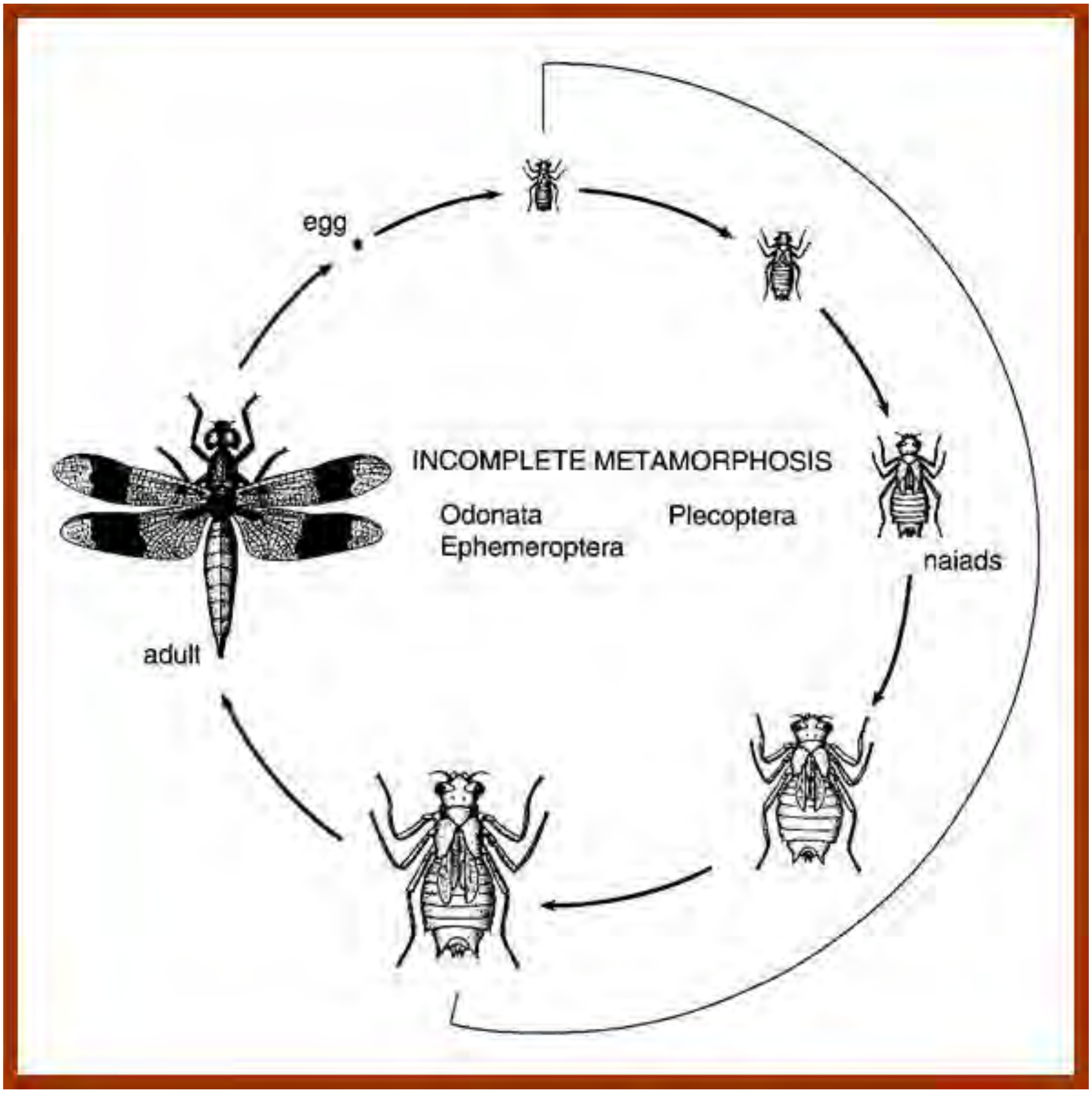


Fig. 5: A lifecycle diagram of a dragonfly, which develops by Incomplete metamorphosis

You've probably all viewed the lifecycle of a butterfly, beginning as a tiny egg, and then hatching into a caterpillar, which grows and pupates into a chrysalis, and eventually emerges as a butterfly. This is known as **Complete metamorphosis**. What you may not know is that most insects develop in this fashion, including things like beetles, flies, and ants. This is considered the pinnacle of insect development as so many successful species are included in this group. It is thought that insects developing through complete metamorphosis are so successful because they often don't have to compete with their offspring for food and habitat needs; the immature and the adults often lead very different lives.

It's important to note that this type of metamorphosis includes a "resting" stage before the adult stage that is generically know as a **pupa**. Pupa generally don't move and have reduced metabolic rates, making them environmentally resilient. Some species can remain as pupae for many months and can wait until favorable conditions before emerging as adults. Many insect species in Michigan spend the long cold winter in the pupal stage.

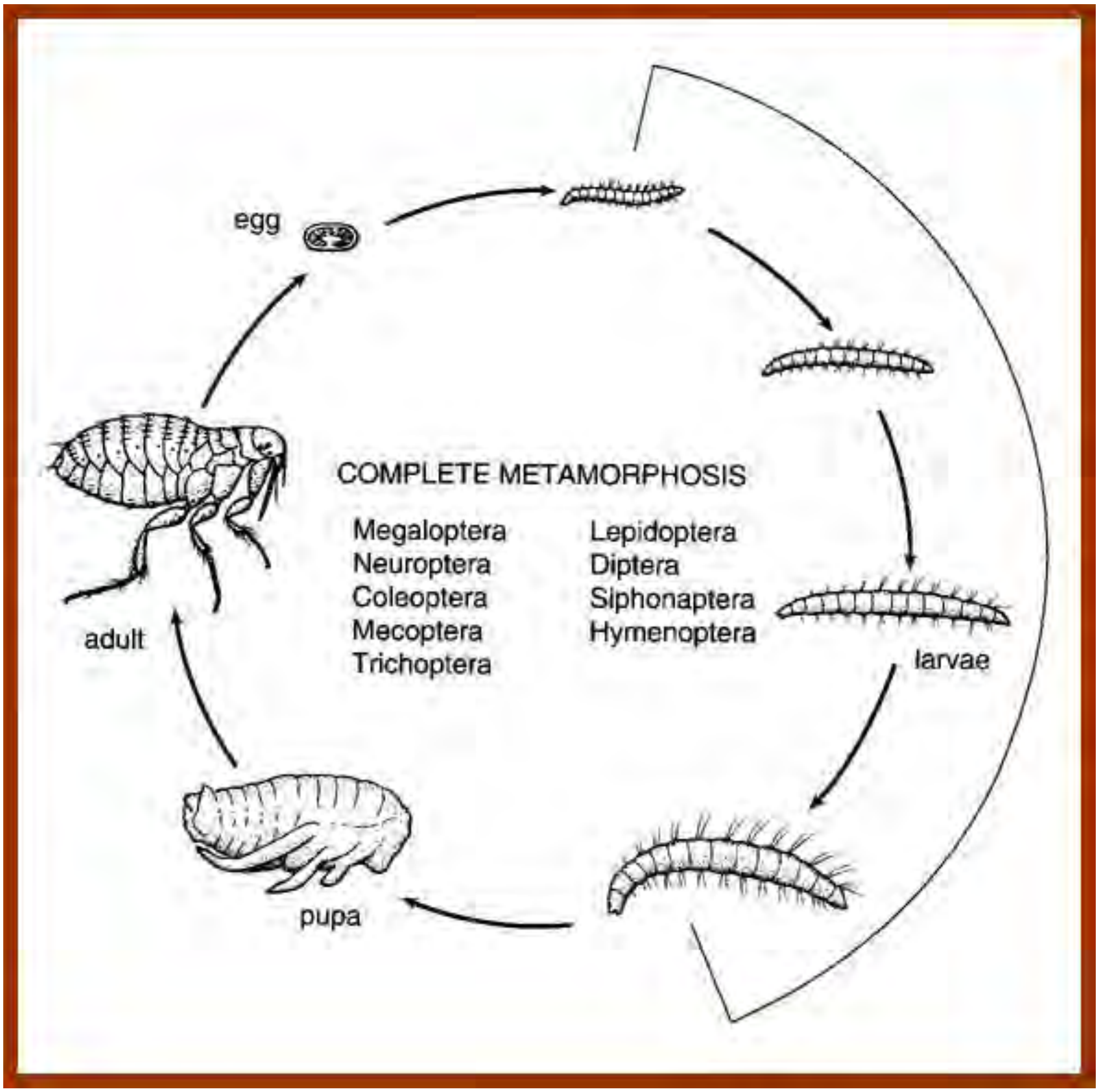


Fig. 6: A lifecycle diagram of a flea, which develops by Complete metamorphosis