Entomology

Reference Guide

CANADA

4-H Saskatchewan

4-H Motto

'Learn To Do By Doing'

4-H Pledge

'I pledge
My Head to clearer thinking,
My Heart to greater loyalty,
My Hands to larger service,
My Health to better living,
For my Club, my community and my country'

CANADA
4-H Saskatchewan

4-H Grace

(Tune of Auld Lang Syne)

We thank thee, Lord, for blessings great
On this, our own fair land.
Teach us to serve thee joyfully,
With head, heart, health and hand

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Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

AGRICULTURE COUNCIL OF SASKATCHEWAN INC.

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Introduction

Objectives

Successful completion of this project should allow members to:

- Understand traits that define insects.
- Use the “key” method of identification to identify insect specimens.
- Learn basic entomological terminology, with special regard for insect body plans and life cycles.
- Understand the importance of insects in ecosystems.
- Understand the role that insects play in agriculture.
- Get a feel for the immense wealth of insect diversity.
- Locate, observe and identify local insects.
- Distinguish between main types of insects, and their associated habitats.
- Build and set traps to capture local insects.
- Carefully observe insect behaviour.
- Respect the delicate nature of insects.
- Work with other group members to further their progress in learning.
- Learn how to work with their insect field guides to better understand terminology or concepts.
- Learn how to record insect collection information in a field notebook.
- Understand how humans influence insect populations and how insects influence human life.

Requirements

- A magnifying glass or an eye glass – this is very important because insects are often very small, and without a magnifying glass you may not be able to see important details such as size or body characteristics.
- Clean glass or plastic jars, preferably of different sizes with lids that have holes punched into them by a supervising adult.
- A butterfly net, preferably one that is lightweight and foldable, but any net that is fairly large but easy to carry around will do.
- A lined notebook that will be used as your field notebook.
- Curiosity and a sense of adventure!

Tips for Success

- Attend club activities regularly.
- Listen and ask questions; work with your leaders and well as with other club members.
- Keep your field notebook and a pencil handy as often as possible – the best way to learn how to take notes is to practice, and you never know when you'll see an exciting new insect.
- Share any new discoveries or knowledge with others – this will help you remember what you've learned, and teach others why insects are important.
- **Be patient!** It takes time and practice to learn new words, and even more time and practice when it comes to looking for insects and examining them carefully. Rushing might cause you to harm the insect you are studying, which is something you very much want to avoid. The greatest lesson to be learned is respect for your surroundings and the environment, and that means leaving the inhabitants of that environment as you found them once you have finished observing them.
- Ask questions if something is unclear, or if you see something you haven't seen before. Asking lots of questions will help you learn even more, and it will also keep you safe. As we'll discuss later, some insects can be harmful if handled, so it's important you ask questions to more quickly identify how close is too close to certain insects.
- Remember to have fun! Think about how small insects are, and yet they manage to survive in our world, even with so many predators and dangers. Insects are truly amazing creatures; consider this as you study them, and you will quickly learn to appreciate them, and enjoy the knowledge you gain from studying them.

Achievement Requirements for this Project

- A completed safety activity, with an outline of the most common stinging or biting insects found locally.
- A completed field notebook with drawings and descriptions of at least three different types of insects (e.g., beetle, dragonfly and butterfly), and completed discussion questions for activities participated in.
- A completed insect identification, or "keying", activity.
- Create either a pitfall trap or an aquatic insect trap.
- Completed project about local invasive species, and their effects on local ecosystems.
- A completed "Franken-bug", with descriptions of all the insect parts used.
- Completion of the "Metamorphosis" exercise, and a good understanding of the main stages of metamorphosis.
- Answers to the "World of Insects" activity.

Tips for Staying Safe

Insects are adapted to survive in the places where they live (called "habitats"), and are very capable of defending themselves from predators. Because you are so much larger than they are, insects will always perceive you as a predator. So, when observing them – and especially if attempting to handle them – they will respond with defensive action. Some insects hide or flutter about nervously. Others have much more dangerous defences, such as stings or bites. **Never** handle an insect with your hands. This is dangerous to you, as you may get bitten or stung, and it is even more dangerous to the insect, as they may get hurt as you're trying to catch them. Only use a hard container, such as a jar, to capture insects (with the only exceptions being butterflies, moths, dragonflies and damselflies, that may be captured with a net), and only capture insects under the supervision of your group leader, who will help you identify insects that have dangerous defences.

Remember that when you are looking for insects it is easy to get lost or hurt, so always be aware of your surroundings. Even the neatest and rarest insects aren't worth risking your health or safety! Follow your group leader, or only collect insects in areas where you have been given permission to do so. Use the "buddy system": make sure someone goes with you when you are collecting or observing insects.

Resources for Learning

People

- Find out if there are any local entomologists and ask if they would be willing to share their knowledge with you. If you live in a town or city that has a university, check with their biology department.
- Zookeepers or zoologists – visit your local zoo or science museum to see if anyone can give you information on insects or their habitats.
- Your 4-H group leaders, other 4-H group members, maybe even your parent or guardian. Get them involved in your projects, and share with them what you are learning.

Resources

- Entomology handbooks, field guides, magazines or textbooks.
- Television shows and documentaries about insects or invertebrates in general.
- Websites dedicated to insects or the study of entomology, either specifically in Canada, or worldwide. Remember to stay safe while searching online. **Never** talk to strangers online, or agree to meet, **even** if they claim to be able to help you with your projects. It's not safe to meet with someone you don't know. Tell your parents or guardian right away if someone you don't know tries contacting you online. **Never** give out any personal information (not even your name!) to anyone you don't know. Stick to using credible sources of information, like websites designed by scientific institutions, to find information. Using a search engine like Google and typing in "entomology society" or "entomology museum" will help you find the results you want.

Places or Organizations

- Universities, museums and zoos are designed to help you learn, and are great places to find resources.

Introduction to a Miniature World

Around our feet exists a tiny world we can sometimes find hard to understand, or even notice. This world seems so different from ours but, in reality, in many ways it is very much the same. There can be rulers governing societies, and parents caring for young ones as they learn how to survive. There are friendships, battles and chances to learn from mistakes. Of course in this world, everything happens much faster. A single season in our world can be the length of a lifetime, or many generations of lifetimes, in this tiny world. A great many things happen very quickly, and so may be easy to miss. This project manual was created to help you (yes you!) learn how to pay closer attention to the creatures that inhabit this miniature world, and to begin to understand how much this world is truly a part of our own.

What is an insect?

The main group of animals in this miniature realm are insects. While there is only a single species of humans living on this planet, there are at least *six million* insect species. Talk about outnumbered! But what are insects exactly? The first key identifying feature of insects is the presence of six legs. Six legged animals can be referred to as **hexapods** (*hexa* – meaning six, and *pods* – taken from the Greek word *poda* – meaning "foot"; together literally meaning 'six-footed"). Most insects also have two pairs of wings. These wings can come in all sorts of shapes and sizes! Butterflies for example, are insects that have very large, often colourful wings. Beetles also have wings, but the first set is hard and folded to protect the thin and fragile wings underneath that are only occasionally used to fly. Insects can also be recognized by their hardened bodies. We humans have soft, fleshy bodies with hard bones making up the skeletons beneath our skin. Insects are different and seem a bit inside out. They are very soft on the inside, and have a hard layer on the outside of their bodies, like a shell. This layer is called an **exoskeleton** (to help you remember, note that *exo* means "outside", and *skeleton* in this case of course refers to the hardened shell.) So when deciding if a living thing is an insect, look for six legs, two pairs of wings and an exoskeleton. These characteristics will help you identify whether the creature you are looking at is an insect or not.

Spiders, mites, scorpions, millipedes, centipedes and earthworms are often mistaken for insects, or "bugs". In fact, they are not insects at all. Firstly, none of these creatures have wings, whereas most insects do. Secondly, none of these creatures have six legs – most of them have many more. Spiders, mites and scorpions are distant relatives of insects, but they have eight legs, not six. Centipedes and millipedes have many sets of legs. Their names mean "hundred-legged" or "thousand-legged". Not all species of centipedes have one hundred legs, and not all millipedes have a thousand. Usually, centipedes have about 30, and millipedes have between 30 and 400, with one species having 750! It is their large number of legs that helps separate centipedes and millipedes from insects, which you will remember only have six. What about earthworms? Of course, they have none of the features we discussed above. They have no exoskeleton, no wings, and definitely no legs. Therefore, they cannot be classified as insects.

Now that we understand what group of miniature creatures we will be studying throughout this manual, let’s begin to learn how to distinguish between the members of this group. Although insects can be often identified by their similar features (six legs, exoskeleton and wings), these features come in all different shapes and sizes; all in order to help each kind of insect survive in their own habitat.

Insects are Divided into Groups

There are many, many groups of insects. In this manual, we will discuss some groups that you are probably familiar with, along with one or two that may be new to you. The goal of this is to help you understand the incredible **species diversity** found in the world of insects. In other words, upon completing this manual you will start to realize how many different shapes and sizes insects come in, how many different types of insects there are in the world, and how many different kinds of habitats they call their homes.

Insect species are divided into **orders**. An order is a broad group that can be made up of many types of species. For example, all beetles belong to the same order, but if you found any **aquatic** beetle (a beetle that lives in the water), it would surely belong to a different species than a beetle you found in a **terrestrial** (land) environment. They would look similar to one another, but each would have special **adaptations** so that they could survive in their own habitat. An aquatic beetle for example, would have special legs used for swimming, whereas a land beetle would have legs used for running on land. Differences like these help identify insects as different species, but they both still belong to the order of beetles. This is because they have enough similarities (like hardened outer wings, for example, which almost all beetles have in common) that they can still be considered beetles. Identifying different species can be very difficult, even for experts! In this manual we will only learn to tell the difference between some of the most common orders, so don’t worry too much if you have a hard time understanding the idea of a species. You will have a better understanding of these concepts once you have mastered the idea of an order, and have gained some practice looking at and identifying some different kinds of insects.

This reference book will focus on seven insect orders:

1. Beetles (*Order: Coleoptera*)
2. Bees, Wasps and Ants (*Order: Hymenoptera*)
3. Butterflies and Moths (*Order: Lepidoptera*)
4. Dragonflies and Damselflies (*Order: Ephemeroptera*)

5. Flies (*Order: Diptera*)
6. True Bugs (*Order: Hemiptera*)
7. Grasshoppers (*Order: Orthoptera*)

For basic study, write down and remember the **common names** (i.e. butterfly, beetle and so on) of the orders we will be learning about. You may need to ask your group leader for help if you are having trouble pronouncing a name. For more advanced learners, copy down the italicized **scientific names** (also called Latin names) for each order, and try using them as often as you can. This will help you remember them. Sometimes scientific names are difficult to pronounce, so ask your group leader for help and write out how the name sounds in your field notebook (e.g. Ephemeroptera is pronounced "EE-fem-er-OP-ter-ah"). This sometimes takes some practice, and the more you use whatever new words you learn the easier it will be to remember them, so be sure to tell your friends and family about all of the new words that you learn.

It can be easy to tell different groups of insects apart; you can easily tell the difference between a butterfly and a beetle, right? Sometimes however, it can be quite tricky. To tell the difference between insects that look similar, and identify what they are, those who study insects (called **entomologists**) use a *key.* This is not the kind of key you use for a lock. An entomologist's key is a written series of steps, based on visible features of the insect, that help you identify what sort of insect specimen you have found. Each step is composed of two parts. For example:

Step One:

a) Your specimen has six legs – *(Go to Step Two.)*

b) Your specimen has more or less than six legs – *(not an insect)*

Read both of the components of each step carefully. Then examine your specimen to see which category it fits into. **Your specimen must only fit into one category,** so choose the **best** fit. In the example above, step one asks the collector (that's you!) to identify how many legs the insect specimen has. If you count six legs, you would follow the instructions in the brackets and move forward to step two. You would continue reading the subsequent steps, repeating the process of understanding each of the steps and looking for the characteristics in question on your specimen. If your specimen has more or less than six legs, as represented in option b), your specimen is not classified as an insect at all, and therefore could not be identified using a key specified for insects. (Note: there are keys for spiders, and other non-insect creatures as well, but our focus in this project is on insects.)

Below, there is an insect key you can use to help key insects to one of the seven orders we have already introduced. This key only considers adults of each order. We will discuss in the following chapters how adults and their young, called *larvae* (singular: *larva*), differ in appearance. There is a corresponding activity with this key, so be sure that you understand how a key works.

Key to Seven Insect Orders:

Step One

a) Your specimen has six legs. (Go to Step Two.)
b) Your specimen has more or less than six legs. (Your specimen is not an insect.)

Step Two

a) Your specimen has two sets of large, spread out wings. (Go to Step Three.)
b) Your specimen has very small wings, wings that are folded or hardened, or no wings at all. (Go to Step Four.)

Step Three

a) Your specimen's wings are coloured with either bright or dull colours. (Your specimen is a Butterfly or Moth.)
b) Your specimen's wings are mostly clear, or if they are coloured, the body is very long and slender. (Your specimen is a **Dragonfly** or **Damselfly**.)

Step Four

a) Your specimen has its wings folded across its back, and they form an "X" pattern, as they cross each other. (Your specimen is a True Bug.)
b) Your specimen does not have wings folded in an "X" across its back, or it has no wings at all. (Go to Step Five.)

Step Five

a) Your specimen has a set of hardened front wings hiding the bottom pair of wings. (Your specimen is a Beetle.)
b) Your specimen does not have a hardened set of front wings, or if the front wings appear hardened, it has very large hind legs used for jumping, or it has no wings at all. (Go to Step Six.)

Step Six

a) Your specimen has tough front wings that are folded on its back, with large hind legs used for jumping. (Your specimen is a Grasshopper.)
b) Your specimen has only spread, membranous (thin and see-through) wings, or it has no wings at all. (Go to Step Seven.)

Step Seven

a) Your specimen has only one obvious pair of wings. (Your specimen is a Fly.)
b) Your specimen has two pairs of clear wings, often with a colourful body (e.g. yellow and black) or it has no wings at all, often with a black or dark coloured body. (Your specimen is a **Bee**, **Wasp** or **Ant**.)

It is important to understand that the previous example – is a very basic key, and should be used only as a very general guide. If you cannot identify your specimen using this key, you should consult a more in-depth entomology textbook or field guide.

Always keep information about insects you have observed in your field notebook, and write in the steps you took when keying that insect. Writing the steps out, and any other important information about your specimen, helps you learn and remember important characteristics of the insects you have collected. You may also start to notice trends in the kinds of insects you find in certain places. For example, you may notice that you find the most dragonflies near wetlands, or a specific beetle around a particular park. This will give you clues as to the kind of preferred **habitat** insects look for when creating a home.

Identifying insects and keeping track of where you found them will help you recognize the insect diversity in a particular area. You may start to notice, or perhaps you have already, that different kinds of insect populations are associated with different kinds of habitats. For example, you will find different insect communities underground than you would in water, flying around in the air or among flowers. The following units within this reference book have been written to help you understand the different insect communities that occupy underground, **aerial** (in the air), aquatic and agricultural habitats. Understanding what makes these habitats different from one another will help you understand why the insects found within them are also different from those found in other habitats. This will aid you in looking for particular kinds of insects, and the more insects you find, the more knowledge you will have on how the world of insects works and how important it is.

Case Study – The Wetter the Better!
A Closer Look at Wetland Habitats

Often, when we consider habitat types, we may think of areas that are very large and easily identified, such as a forest or desert. We don't always consider smaller habitats. This is perhaps why wetlands may be overlooked at first when you consider places to go to collect or observe insects. Most wetlands are small compared to lakes or rivers, and they may even dry up at certain times of the year. However, these areas house an immense amount of insect life, and so are very important, and interesting, to study. The edge of a wetland is often surrounded by vegetation (plants) that is unique to a partially aquatic habitat. You won't likely find the plants you find on the edge of a wetland in a dry forest or desert! Very often the plants you may see are cattails or buttercups. These plants attract many insects as they provide excellent areas to perch, lay eggs or find food. But sometimes there are also plants in the water. These plants provide important food sources and hiding places for insects that spend part of their life, or even their whole lives, in the water. So what insects can you find among these aquatic plants?

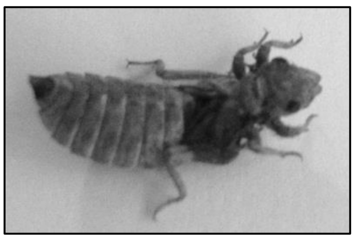


Image 1. Young dragonfly larvae look almost nothing like their parents. To compare, look at the adult version of this species at the end of Unit Two. (*Libellulidae sp.)*

Did you know, for example, that dragonflies and damselflies actually start their lives in water? You may have seen them, but not recognized them, as they look very different when they are in their young, or **larval**, stages. In fact, at first they have no wings and are very often a dull brown, tan or nearly black colour to help them blend in with their surroundings (see Image 1). Because insects have a hard exoskeleton, they cannot grow like you and I do. To get bigger, they grow on the inside and, when the time comes, they shed their skin and crawl out of their old exoskeleton during a process called **moult**. After moulting, they are larger and more similar to their final adult form. More information on this process of change is given in Unit Three.

Wetlands are important habitats for many species that have to undergo these changes in order to grow. Many species are adapted to growing as larvae in water, and just before their final moult they crawl out of the water on the surrounding plants and shed their last larval skin. During this final moult, dragonflies finally reveal their wings, and after soaking up some sunlight to warm up, they can finally take to the air and fly away.

This adaptation to a part aquatic and part terrestrial life is what makes areas around wetlands so rich in insect life. There is always something growing, either in the water, the surrounding plants or even in the wetland mud! In the following units we discuss underground, aerial and aquatic insects. Wetlands are the best habitats to find an example of each of these kinds of insects. Remember that because these areas have so much life, they are very important for the continued survival of these species of insects, and to all the different creatures that rely on insects for food. So if you do go looking for insects around wetlands, treat them with a lot of respect. You are, after all, walking through a home that belongs to many, many creatures. Some great ways to study wetlands with respect are outlined in your activities section (see the aquatic trap building activity). Enjoy your time in a wetland.

Underground Burrowers and Litter Dwelling Insects

We began exploring the world of insects by considering the world that lays around our feet, but what about the creatures that live *beneath* our feet? Many different kinds of insects have adaptations that allow them to spend considerable lengths of time below ground. We will look more closely at two kinds of ground and underground dwelling insects: ground beetles and ants. Ground beetles spend time looking for food (called "foraging") in **leaf litter** – the assortment of dead, dried and decaying leaves on the ground. Before we can go out into the natural world and look for these creatures though, we must first learn some things about them that will help us recognize what they look like.

Litter Dwellers – The Ground Beetles

Below is a general diagram of a ground beetle. Keep in mind that because it is only a general diagram, not all ground beetles will look exactly like this. It is only meant to give you a rough idea of the basic design of this kind of insect.

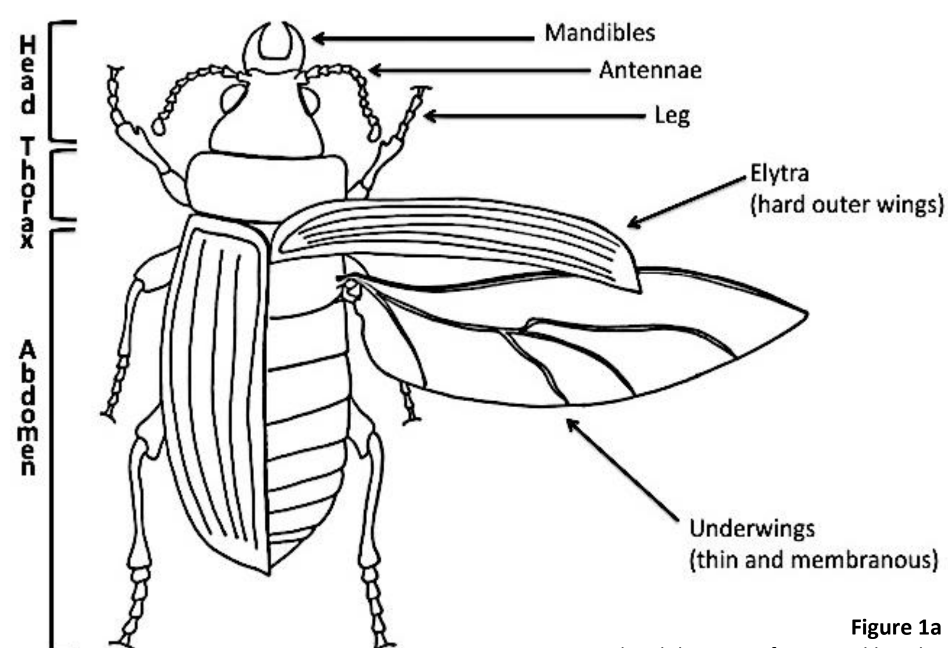


Figure 1a
A generalized diagram of a ground beetle.

Familiarize yourself with the terms used to describe the body parts, or **morphology**, of ground beetles. Notice their pointed mouthparts, or *mandibles*, protruding from the front of their head. They are predators, and these large mandibles help them to catch their prey. Be careful! Some larger ground beetles have mandibles that are so large and strong that they can give you quite a pinch if you try to handle them. Ask your group leader to help you catch one in a jar if you want to examine one more closely, otherwise just watch it where you found it – in its natural surroundings.

Behind their mandibles ground beetles have two *antennae*. Antennae are very important for all insects. They can be used for everything from feeling around their surroundings and figuring out where they are, to communicating with other members of their species. Touching antennae is similar to how we shake hands as a greeting. Ground beetles may also use their antennae to feel around for food or to assess the size and shape of their prey before they attack.

Notice that the antennae are not made up of one single strand, but of several little pieces. This is important. Some beetle species can be identified, in part, by the number of little antennal segments (called *antennomeres*) they have. Can you count how many little antennae pieces are in each antenna in the previous diagram?

The next large segment that makes up a ground beetle behind the head is the *thorax*. The thorax joins the head of the beetle with the rest of its body, called the *abdomen.* The first set of legs can be found attached here. Each of the six legs on a beetle is made up of separate parts (Figure 1b introduces each of these parts). For a challenge, try to learn the names of these parts. Note that only some of the leg parts are visible in the beetle diagram 1a. More parts (the *coxa,* and the *trochanter*) are found beneath the beetle's body. If you are new to studying insects, just remember the basic structure of a beetle leg. Most ground beetles have adapted to moving quite quickly, so their legs are slender and made for running through leaf litter and across the ground. If you find a beetle that has shorter legs that are thick, it is probably a beetle that has adapted to digging. We will discuss this kind of beetle in the Case Study at the end of this unit.

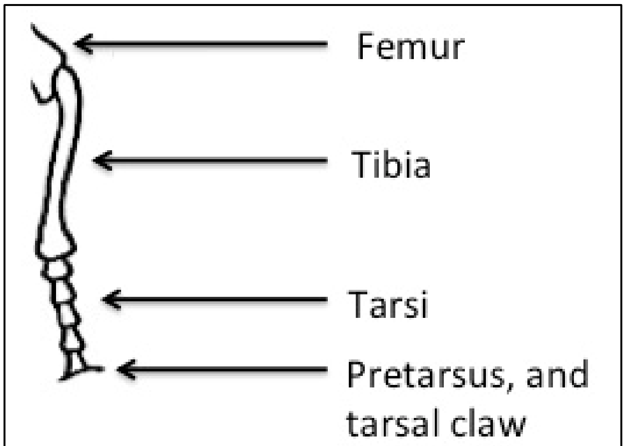


Figure 1b
The parts of a ground beetle's leg

Did you know that most beetles have two sets of wings? It can be hard to see the bottom set of wings as they are hidden under the hard outer ones. The outer wings are used as a defence, like a coat of armour, and are as hard as the rest of the beetle's body. Entomologists call these wings the *elytra.* Some beetles' outer wings can be very colourful. Metallic wood boring beetles for example have very shiny outer wings that look like they've been coated with a colourful shiny paint! Most ground beetles have black or brown elytra that act like **camouflage** to help them blend in with the surrounding ground. However, if you watch them in the light, their wings might reflect the light and look purple or green. When you look for ground beetles, take some time to look at the colour of the elytra, see if you can spot these faint colours, and also take notice of any patterns of texture or colours. Always take notes about the colours and patterns of the beetles that you find – this will help you identify them when you look through your insect field guide later on.

Beneath the hard outer wings are the underwings. Because these wings are thin and fragile, we can refer to them as being *membranous*, meaning "like a membrane". The lines within the wings are *wing veins* and they help strengthen the delicate underwings. In some beetle species the underwings are used to fly. Beetles do not fly well because their hard front wings prevent them from flying for long distances. They usually cannot fly very quickly either. However, even a poor ability to fly can come in handy when you're in danger. If you happen to see a beetle in flight, try to watch where it lands, and observe the complicated technique it uses to fold its underwings back under its front wings. It can feel like you're watching a Japanese master of origami!

There are species of ground beetles that have entirely lost the ability to fly because their front wings are fused (permanently joined) to their underwings. This provides them with a stronger coat of armour around their bodies, but means that they cannot fly. Weevils are an example of a group of beetles where many of the species cannot fly. This is not a problem for them however, as they spend much of their time underground, feeding on plant roots. This extra-hardened shell prevents them from getting crushed underground, and helps them dig further down in search of food.

Adaptations help organisms survive in a particular habitat or in certain circumstances. Consider the differences you see between different ground beetles you find, and the habitats you find them in, and write in your field notebook possible reasons for these different adaptations. For example, if you find a black ground beetle in a forest with dark soil, write down the adaptation you observe the beetle has to live in that habitat. In this example, the ground beetle's dark colour helps it blend in with the dark soil on which it lives.

Now that you know what a ground beetle looks like, you can try your hand at finding and observing them. Count how many different kinds you find, and remember to take notes. It can be difficult to find ground beetles depending on the time of year you are searching for them. You can improve your chances of finding them by setting traps as a group, supervised by your group leader. You will find instructions on how to do this in the activities section.

Cities in the Soil – Ant Empires

As you look for ground beetles, you may notice another kind of insect living amongst the leaf litter. In fact, these insects are very common and you've probably already encountered them. They can be found in almost any habitat, including (much to some people's dismay) our own homes. During the warm season, you may be interacting with **ants** almost daily, maybe without even realizing it. They are some of the smallest insects that most people are familiar with. But did you know that although you see them regularly, most ants actually build their entire societies underground? Ants' underground societies are often referred to as *anthills,* or **colonies**. Take the time to observe the behaviour of ants and begin to understand the complex relationships these amazing creatures have with their environment, other insect species and one another.

We might think that having living quarters underground would be dark, damp and unpleasant. This may be true, but ants build amazing structures, including passageways, nurseries for their young ant larvae, storage rooms for food and most importantly of all, a large royal chamber which houses their colony ruler: the queen ant. Most of the ants we see are worker ants, looking for and collecting food. These ants are usually quite small and live relatively short lives. But a queen ant is usually large, and can live up to 30 years. As you begin to study ant colonies, consider that somewhere within their complex society may live a queen that is as old, or much older, than you are. See Figure 2 for a general diagram of what an anthill might look like underground. Pay special attention to the purposes of each chamber.

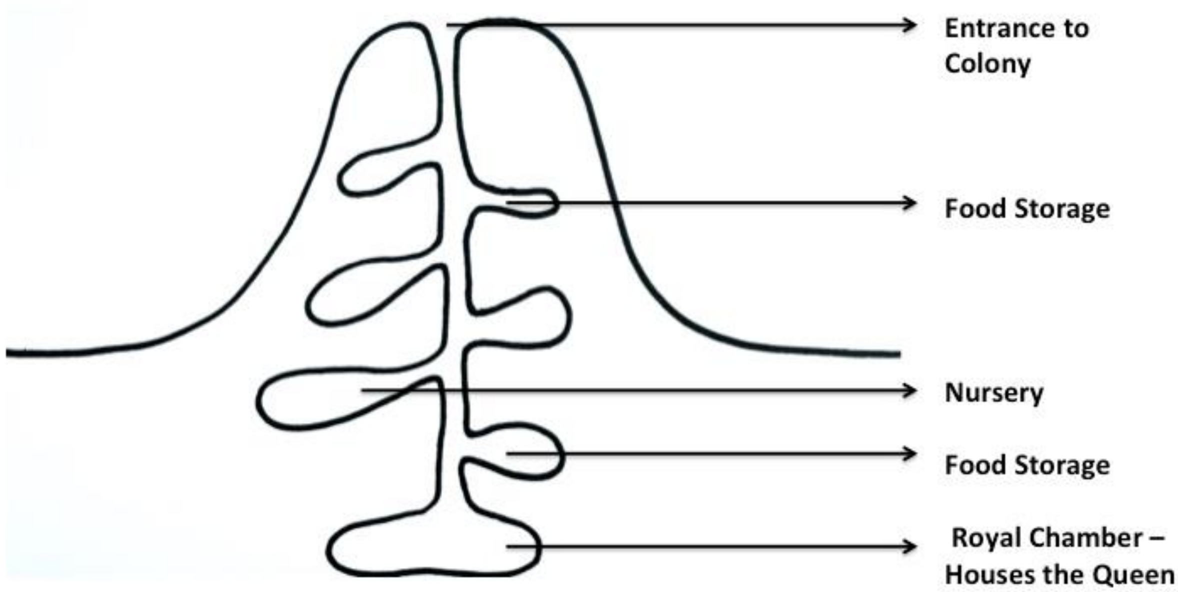


Figure 2. Basic structure of an ant colony. Notice how there may be more than one food storage chamber, depending on the size of the colony. There may also be more than one nursery or entrance to the colony, but only one royal chamber.

Notice that unlike the ground beetles we discussed before, ants are very social creatures. They live in groups that may number in the millions. This is made possible by the careful way in which ants communicate. They can 'talk' to one another by using their antennae. If you look closely, you may see two ants stop and feel each other with their antennae. This is the ants way of saying, "Hello!" or "Have you found any food?" or "Where have you been?"

Ants are born into different roles. Small, infertile female ants are the *workers* of the colony – they are normally the ones you find around your home or garden, looking for food to bring back to the colony. Some infertile females can also be the *soldiers* of the colony. They can defend their colony from attacks by predators by fending them off with their powerful jaws. They also defend the workers as they collect food, and some band together to stage attacks on rival ant colonies. Fertile males within a colony are called *drones.* They can develop wings and fly to meet princesses (fertile females, and potential queens). Together, they have the chance to begin new **colonies** where the princess will become a queen in her own colony. Like winged drones, princess ants also have wings, but lose them when they become queens. It is remarkable to think that despite their tiny size these creatures have societies that rival the structure and complexity of our own.

Ants play many vital roles in the environment. Their colonies aerate the soil, allowing for better plant growth, which in turn results in more food for a multitude of species. Ants themselves are a food source for a great variety of species. We may think of these tiny soil dwellers as lesser than us, but consider how hard they work to maintain their colonies, feed and look after one another, and how many habitats would collapse without the presence of these vital little lives, and perhaps you will begin to look at them a different way.

The soil is rich with life packaged in all shapes and sizes. It is a good place to begin looking for insects to learn about, to observe the differences between social and solitary insects and how their behaviour differs. The **carnivorous** ground beetles eat other animals and must hunt for their food, whereas the mostly herbivorous ants eat plants and must go out to gather leaves, seeds and other plant parts to keep the colony thriving. For these creatures, each day is a struggle, full of dangers, and yet they continue to survive. Try out the “Pitfall Trap” activity in your activity book to get a closer look at the ground dwelling species that exist around you.

Throughout this unit we have adjusted our eyes to examine the ground, hunting for beetles and large underground societies. Now that we have conquered the land, the next unit leads us to conquering the next domain of insects: the air.

Case Study – Waste is not Wasted Space: The Story of the Dung Beetles

Imagine what your neighbourhood or local park would look (and smell) like if nobody cleaned up after their dogs? Disgusting, right? Animal waste, if left untouched in habitats, would cause very harmful effects to surrounding plants and animals. Diseases would spread much more quickly, water would become contaminated and life in all its forms would become difficult to sustain. We owe nature's "clean up crew" a great deal of thanks for keeping our environment free of harmful waste. This crew consists of a variety of bacteria and animals, and insects often play one of the most major roles in this maintenance. Perhaps the most notable of these tidying insects is the family of dung beetles.

Dung beetles come in many shapes and sizes, but often have a distinctly rounded body, and the males often have a small horn on top of their heads. They also have thick, squat legs used for digging. Dung beetles are common in Canada, with about 34 species on the Canadian grasslands alone. They can fly, but are most often found on the ground, rooting around cow manure or other animal waste found on pasturelands.

Why do they choose such a stinky substance to inhabit? Remember how we mentioned that they have thick, squat legs. In fact, many kinds of dung beetles can use these legs to roll pieces of animal waste into rounded balls. By pushing these dung balls with their hind feet, dung beetles can roll the manure ball into a burrow they have created. This kind of dung beetle is referred to as "rollers". Once they have moved their dung ball into their lair, a pair of dung beetles can safely lay their eggs. When the young hatch as larvae, the ball of manure serves as an excellent meal for them.

How do dung beetles know to find the way back to their lair once they have collected their dung? This question has baffled scientists ever since their strange, rolling behaviour was first observed. They can actually travel great distances with their balls of dung. Recent research suggests that since rolling dung beetles are largely **nocturnal** (active at night) they can actually use stars as navigational tools to help them find their way home. The next time you're outside on a warm summer night, and you look up at the stars, consider that there may be a dung beetle looking up at those same stars, just trying to find its way home again.

Taking to the Sky – Insects in Flight

Perhaps the most noticeable insects are the ones you see in flight. Undoubtedly you have experienced, maybe even more than once, the buzz as a dragonfly whizzes by your head, or the serenity that comes with watching a butterfly flutter amongst flowers in a flowerbed. It is even more certain that you have at least once swatted a fly from your meal or a mosquito from your arm. But have you ever stopped to think how they are capable of such patterns of flight? Or why they have even evolved such an adaptation? We saw in our previous unit that some species of beetles have the power of flight as well, but their periods of flight are brief and they do not stay in the air for very long. Surely, it must be exhausting to be a dragonfly, seemingly always in motion. Let's take a closer look at the body structures that allow insects to fly long distances, and how that remarkable adaptation has allowed them to reach new heights in regards to survival.

Fairy Tales in Flight – Dragonflies and Damselflies

Have you ever stopped to count the wings on a dragonfly or damselfly? See if you can spot the two frontal wings and the two hind wings the next time you spot one perching. These four wings give dragonflies and damselflies an incredible range of motion. They can fly up, down and side to side very quickly. Let's examine these wings and see what makes them so unique and capable of such incredible feats of flight.

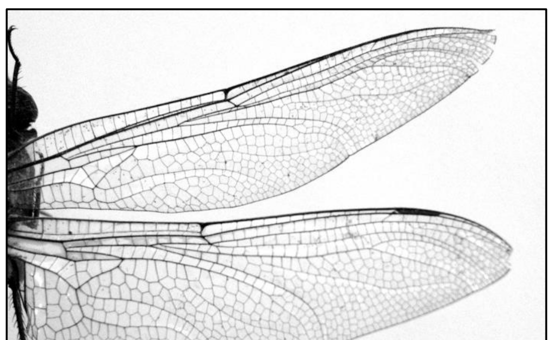


Image 2.
Dragonfly's network of wing veins (*Aeshnidae sp.)*

Dragonfly wings, like most of the insect body parts, are made from a very thin extension of the exoskeleton. If you look very closely at a dragonfly when it is sitting on a branch, or perching, you may see that the wings are indeed incredibly thin! Now notice the spider-web like lines running across the wings. The patterns these lines form, called **venation**, are important for strengthening the wing. You may notice that the veins at the front are particularly thick. These have an exceptionally important role in wing strength, and help prevent the wings from tearing as the dragonflies and damselflies fly through the air and vegetation.

Identifying dragonflies and damselflies can be tricky business! Remember the insect key we used in the first unit to tell different kind of insects apart? Read through the following key (we will just use one step here – focus on the details between the two descriptions) to help you understand the differences between a dragonfly and a damselfly:

Step One:

a) The specimen has a thick, strong and usually shortened body with wide, broad wings. The eyes are very close together on the head – they may even touch at the centre. When perching, the wings are always held outstretched, never folded over top of the body. – Your specimen is a **Dragonfly**.

b) The specimen has a long, slender body that looks very delicate and thin. The wings are also very long, or *elongated,* and in many species are folded over the body when resting. The eyes are also spaced very widely apart. – Your specimen is a **Damselfly.**

If you have trouble remembering these differences, think of their names. *Dragon*flies are bigger and fiercer, like the mythical dragons. They are brave, fierce hunters, catching prey in midair and so must fly very quickly! *Damsel*flies are thinner and more delicate, like a *damsel* – damsel is a word you can use to describe a young girl. Of course, young girls are also very brave and fierce. But, they are much smaller and more delicate when compared to a dragon. So they also depend on ambushing their prey, and catching prey that is a smaller size than what dragonflies catch. Thinking about meanings of the names of different insects can help you remember what they look like.

Once entomologists have identified whether they are looking at a damselfly or a dragonfly, they can use the wing venation as a method of identifying what species of dragonfly or damselfly they are observing. Besides adding strength, wing venation is like the fingerprint of each particular dragonfly and damselfly species. Each species has a unique pattern of veins on their wings, and close examination of this pattern can help you decide what species you are observing.

Some common species of dragonflies for example, have a characteristic 'boot-shaped' wing venation on the bottom part of their hind wings (see Image 3). So if you examine the hind wings of a dragonfly and see a boot shape, right away you know some more information about what kind of dragonfly that specimen is! Looking closer at the shape of the "boot", and some other important wing venation characteristics, can tell you exactly what species you are examining.

Image 3
This dragonfly species has a characteristic ‘boot-shape in its hind wing. Can you see the outline of it? Hint – look at the shape the arrow is pointing to on the bottom right wing. Can you find a similar shape in the wing on the bottom left? (*Libellulidae sp.)*

The Shift Workers – Butterflies and Moths

Surely the most well-known insects, highly regarded for their colourful beauty and grace in flight, are the butterflies. As a group they are surely the showiest, with large fluttery wings often (though not always) covered with a dazzling array of colours. Tropical butterfly species might come to mind when thinking of butterfly species we may know, but Canada has an incredible diversity of these extraordinary creatures. In this section we will investigate the differences between butterflies and moths, and learn about their unique life cycle and adaptations that allow them to live in a wide range of habitats.

What is a butterfly? Looking closely, we can see that they have four wings, like a dragonfly or damselfly, and yet we know that they are a different group all together. Butterfly wings are much broader than those of a dragonfly or damselfly – this is usually the first thing that gives them away. Because of this, their flight is often much slower. They aren’t in any rush. Unlike dragonflies or damselflies, butterflies are not predators. They feed on **nectar**, the sweet juice produced by flowers to attract insects. And because flowers have nowhere to go in a hurry, neither do the butterflies that feed on them.

Moving slower certainly has its perks; butterflies use less energy to get around. However, this slower movement make them more likely to be munched on by predators like birds. This is where a butterfly's colour and pattern play a critical role in its survival. To us, butterflies are simply beautiful to look at. To predators, the display of colours and patterns can be very confusing. Have you noticed that many butterflies have big circles on their wings? These circles, to a hungry predator looking for a quick meal, can actually look like eyes. They are called *eyespots.* So when a butterfly sits on a flower to feed and senses a predator nearby, it may open its wings to reveal its eyespots. This might scare away the predator, as it jumps back thinking that this meal is actually much bigger than it originally thought, with such huge eyes! If the predator is bold enough to pursue the creature with the large eyespots, it may actually aim a blow at the eyespots, thinking it will blind its opponent, or capture it by aiming for what it thinks is the head, when in reality it has been fooled! Predators will often punch a hole right through the wing, giving the butterfly a chance to fly away as its body remains intact. A damaged wing is a small price to pay when the alternative is your life!

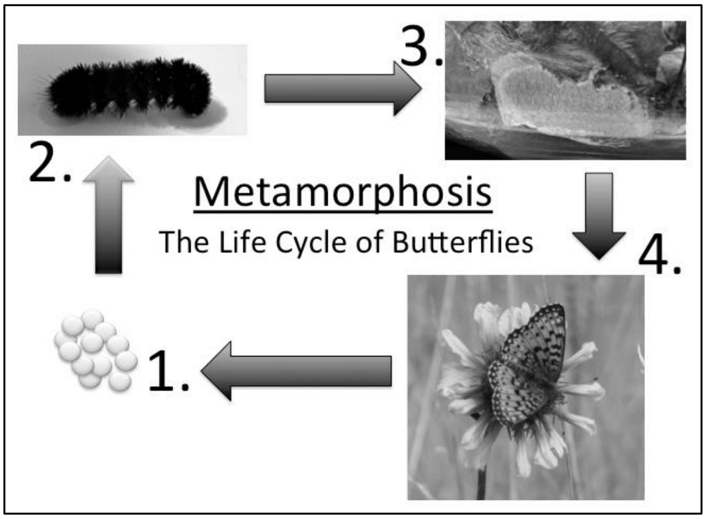


Figure 3
This diagram of metamorphosis shows the different life stages of different species of butterflies. When put together, they are meant to give you an idea of the process of metamorphosis. Let's take a closer look at what's happening in this diagram, beginning with the eggs.

1. An adult female butterfly lays her eggs in a safe place in hopes that they will hatch.
2. The eggs hatch successfully (how exciting!) into little caterpillars. These caterpillars eat and eat until they can grow no more… (*Pyrrharctia Isabella)*
3. Each caterpillar constructs a special case of silk called a *cocoon*. They will stay in here, and allow their bodies to change. *(Polyphemus sp.)*
4. After some time, the caterpillar emerges from the cocoon, now a beautiful adult butterfly that can fly from flower to flower, sipping on sweet nectar. If the butterfly is a female, once it finds a mate, it can go on to lay its own eggs that will someday hatch. (Nymphalidae sp.)

It is important that you recognize a distinction between butterflies and moths. "Butterflies" are usually what we call the day shift workers; the nectar gatherers of sunny summer days. They are usually brightly coloured to blend in with the flowers they feed upon, or to confuse their predators as described above. What we call "moths" are the night shift workers. They are the ones who appear as the sun sets, feeding on plants that bloom at night. They are often more modestly dressed, in shades of brown, black, dull red or rusty orange. This helps them blend in with the dark of the night. Taking their nocturnal habits into consideration, it seems simple and obvious to separate moths from butterflies. In fact, they are so closely related that they fall into the same overall group (Order: *Lepidoptera*). So when we describe butterflies in general terms, we are really describing moths as well. They each share a similar life cycle, described in Figure 3.

Recall that in the Wetland Case Study in Unit One we briefly discussed how some species of insects go through a process of change, where they first come from an egg and appear as something very different from their parent. Their parents have wings; whereas these newly hatched young insects have none. They must go through a great deal of changes before they finally resemble their parents. Butterflies are one of the kinds of insects that go through such a remarkable change.

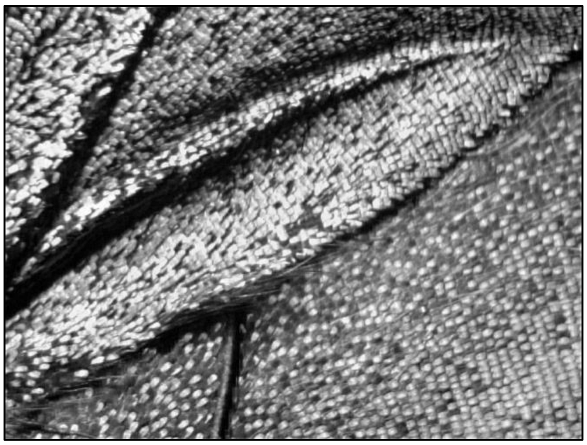
It begins when a female butterfly chooses a place to lay her tiny eggs. She may choose a twig, leaf or any surface that seems like a safe place to begin her family, and provide them with food once they hatch. She carefully lays her eggs on the surface, and once she is finished, her work is over. From now on, the young must fend for themselves.

When they hatch, young butterflies are hardly recognizable. They are long, with no wings, and may have many legs. These help them climb branches, and for the start of their young lives they will rely heavily on their many legs to carry them to tasty leaves, their main source of food. Young butterflies without wings are called **caterpillars***.* Over the course of the coming weeks, a butterfly caterpillar can grow over 300 times heavier than when it first came out of its egg! To grow so quickly, caterpillars are capable of eating an enormous amount of leaves, and so may be harmful to some plants. This is discussed further in Unit Five.

Once the caterpillar has grown to a certain size and reaches a certain age, it begins to show some extraordinary behaviour. It finds a safe place and slowly creates itself a home. It may occasionally build this home from leaves or surrounding sticks, but chiefly it uses thin, but very strong threads of *silk*, which the caterpillar itself produces. After spinning many layers of silk around itself, the caterpillar is safe in its new home and begins its amazing transformation. This special silk house is called a *cocoon.* In the cocoon the caterpillar slowly starts to grow wings, and a more slender elegant body adapted to flying. This growth may take many months – in many parts of Canada the caterpillar remains in its cocoon over the entire winter.

In the spring the caterpillar emerges from its cocoon, except it is no longer a caterpillar. It is now a beautiful adult butterfly that looks almost exactly like a copy of its parents. The butterfly sits in the sunlight for a while, warming its wings, and after a moment it is ready to fly off, no longer looking for fresh green leaves but now in search of sweet nectar from flowers. One day it will find a mate, and the process will begin all over again as the female lays the next batch of eggs in a safe place.

This kind of life cycle, where the insect without wings is born from the egg, but develops them as it turns into an adult, is called *metamorphosis* (see Figure 3 to review this cycle again.) Make sure you understand the different stages of metamorphosis, and try to find each stage when you are looking for insects! Remember that caterpillars eat leaves, and so looking on the undersides of leaves is a good place to try to observe how a caterpillar eats. In the fall, look for cocoons in safe, dark places. Around gardening equipment, or backyard decks are good places to look. If you want to see different adult butterflies, finding a garden or a field with many blooming flowers will surely be a good place!



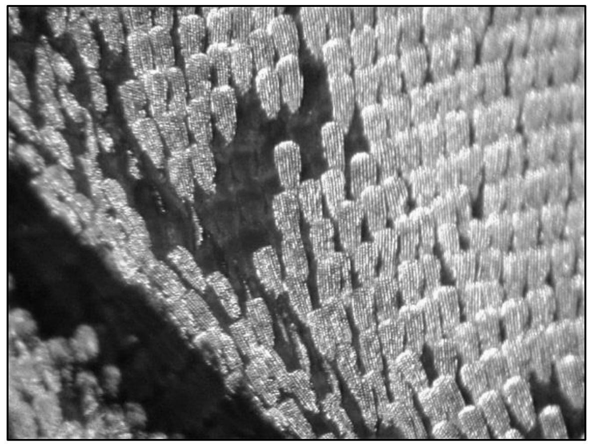


Image 4. *(top left)* a close up of a butterfly wing scales, and wing venation.

Image 5. *(top right)* a close up of butterfly wing scales. (Both specimens *Papilionidae sp.)*

When watching butterflies, it is very important to remember how fragile they are. Not only are their wings very thin, but also the colour on their wings actually comes from hundreds of thousands of little pieces put together, almost like shingles on a roof (see Images 4 and 5 above). These shingles are very light, and so do not weigh down a butterfly. Each one can reflect light a slightly different way, and thus produce amazing colours when viewed from a distance. These shingles are extremely delicate though, and the slightest touch from even the most gentle young entomologist can remove many of them, thus damaging the colour of the butterfly's wings, and making them less effective for predator diversion and flight. Make sure that you only study butterflies with your eyes once you capture one, and always have a group leader help you catch and release your butterfly specimens.

Flies and Wasps

We have discussed butterflies and moths at length, but they are by no means the most diverse or even most common flying insects present in the natural world. That title must surely go to the flies. The order Diptera, which is the group consisting of all flies, is incredibly large, and the species displays incredible variation. Did you know for example, that mosquitoes and houseflies are actually part of this same group? Houseflies are actually more closely related to mosquitoes than they are to wasps or bees. Remarkably however, many fly species pretend to be wasps by imitating their bright yellow and black colours. This helps flies deter certain predators. But how do we know what is a fly and what is a wasp or a bee? The simplest way to tell is to look at the number of wings. All members from the group of flies, including mosquitoes, have only two wings. Wasps and bees have four wings, or two sets of wings – the front and the hind wings.

More incredibly, wasps are actually more closely related to ants than they are to flies. Recall from Unit One that all ants, bees and wasps belong to the same order (*Hymenoptera*). Ants are simply wasps that have adapted to living underground, and so have largely lost their ability to fly. One common wasp in Canada is the yellow jacket. This species and others like it are *omnivorous*, meaning that they eat many types of food. You've likely seen yellow jackets buzzing around garbage cans, feeding on scraps of food, or even drinking sugary soda or juice right out of the can. Many other species of wasps feed primarily on nectar from flowers, but the larvae of these species eat something altogether different. These species of wasps are *parasitic*, which means they benefit at the expense of another species (called the *host*). In the case of parasitic wasps, the adult wasp will sting and paralyze the host insect, then lay an egg inside it. When the egg hatches, the developing wasp larvae benefit by feeding on the insect host until it is big enough – then it eats its way out. It's like something out of a horror movie. The larva then forms a cocoon and develops into an adult wasp. As mentioned, the adult wasp is a vegetarian and eats nectar. Bees also feed on nectar and you've likely seen honeybees or bumblebees buzzing around flowers in your garden or local park. We'll talk about bees in more depth later in this reference book.

Observing wasps and bees can be dangerous. Remember to *never* try to handle a wasp or a bee as they have a very powerful anti-predator response – they will sting when threatened! If you find a wasp or bee in your net as you try to catch any other kind of insect, tell your group leader right away and ask them to release it safely! Otherwise, remember that **if you don't bother them, they will not bother you!** Wasps and bees only sting when they're scared or threatened, so if you leave them alone they have no reason to be afraid of you, and won't pay any attention to you. If you do see a wasp or bee coming close to you, just stay still. Swatting at it will only scare or anger it, and that's when you get into trouble. It is best to just stay still, or if you're nervous, just stay still and call your group leader or a friend over to tell you when it's flown away from you before you can move again. Complete activity one in the activity section to learn more about wasp and bee safety.

Insects easily colonized the land and soon after took to the air. There remains one more type of habitat however that provided a whole new set of challenges for insect life – freshwater. In the following unit we will look at how insects managed to effectively colonize lakes, rivers, streams and wetlands.

Case Study – Nightly Lightshow: Observing Fireflies

A most brilliant and dazzling light show can be seen around Canada. No, it isn't just during the Canada Day firework celebrations! In the plainest of country roadside ditches, and at edges of woods, once the sun has set, little lights in the air begin to blink. Sometimes there are only one or two, sometimes several dozen, and sometimes even hundreds. The creatures responsible are fireflies, although truthfully they are not flies at all. In fact they are a kind of beetle. The light they produce is the result of a chemical reaction in the abdomen of the flying beetle. This special reaction produces no heat – it's not like a light bulb that when left on heats up. It produces what is called "cold light", and so the insect is able to glow, or blink light for a short period of time, without heating up its body and hurting itself. This production of cold light is called *bioluminescence*. Why do fireflies produce this light? This is the beetle's amazing attempt at attracting a mate. The males try to impress the females with the quality of their light display. Much like the way people buy flashy cars or clothes to impress others. During the day, they often hide in vegetation surrounding marshy, moist areas, or woodlands. But in the dark of night, all of these complex chemical reactions and mating behaviours result in what we see as a stunning roadside lightshow!

Diggers, Divers and Bottom Dwellers – The Aquatic Insects

In Unit One, we explored wetlands as sources of enormous insect diversity. Indeed, wetlands host a wealth of aquatic, **semi-aquatic** ("partially-aquatic") and land loving species in and around their waters, and are therefore very important in maintaining a great insect diversity on many landscapes. But insects have colonized moving waters as well. This unit focuses on the permanent and non-permanent water dwellers: those insects that burrow into the sediment of rivers, streams and still waters (lakes and wetlands); insects that dive down into the watery depth for food or shelter, but still must come up to the surface occasionally to gulp down fresh air; and, finally, those creatures that spend the majority of their lives – if not their whole lives – clamouring along the murky bottoms of aquatic systems.

Survival Strategies for Swimmers

Recall the basic body plan of a ground beetle from Unit Two. These beetles have legs that are adapted for running on land. These rounded and thin legs would not be very good for swimming. It would be like us trying to use a broom handle as a paddle for a canoe. Yet there are beetles that live in bodies of water. How do they manage? Firstly, they are adapted to their aquatic environments because they possess strong swimming legs. These are often flattened, with long, stiff bristle-like hairs, called *setae* that help propel them through the water. Aquatic beetle bodies are often more oval-shaped and flattened to help them slice through the water as they swim. Many aquatic beetles are predators, so they are able to swim very quickly in order to overtake and hunt down their living prey. In addition to body plan adaptations allowing them to swim with ease, aquatic beetles also found a unique way to overcome the greatest problem that comes with living underwater – breathing! Aquatic beetles do not have gills like fish, and so cannot breathe underwater. They must, every so often, come up for air. But unlike you and I, who would have to come up every several seconds or so to gulp down some air as we swim underwater, aquatic beetles can stay submerged for great lengths of time. This is because as they come up to the surface, they collect an air bubble that clings to their body. They use the air from this bubble to breathe, and can stay submerged under water for longer periods of time. With their own portable oxygen supply, it's as if they're insect scuba divers.

This seems like a very good adaptation to living underwater, and yet other insects have still different and more unbelievable mechanisms for breathing in these environments.

Water Scorpions: Fiendish Predators or Loving Parents?

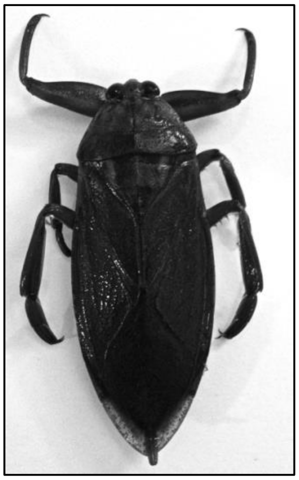


Image 6
An adult water scorpion (*Belostoma americanum).* Notice the caudal siphon, which looks like a tiny tail protruding from the water scorpions rear.

Among the leaves of emergent plants along the shores of wetlands and ponds lurks another predator, much larger than any of the predatory aquatic diving beetles. This creature is able to sit submerged in shallow waters for long periods of time because it has a specialized breathing device called a *caudal siphon* (see Image 6.) This creature is a **water scorpion.** Its caudal siphon is a long, thin tube through which it can breathe: the siphon breaks the surface of the water just like a snorkel. Sitting concealed on the bottom of the wetland, camouflaged in the muck by its dark coloration, the water scorpion waits for passing prey. Due to the large size of water scorpions (some species in Canada can reach up to 6cm) their prey may consist of anything from insect larvae, to small fish. Their most sinister adaptation reveals itself once they have caught their prey. With a lightning-quick jab of their front legs, they impale their passing prey on their claws and inject their meal with special digestive saliva, quickly killing and liquefying the innards of their victim. They then suck up the nutritious juices from their prey through their specialized mouthparts, which are shaped like a sharp, short straw. Entomologists call this type of sucking mouthpart a **rostrum***.* Having fed, they settle back into plant debris on the bottom and hide, until they feel hungry once again.

Such ravenous hunters must surely be cold-hearted creatures indeed! But you might reconsider that assessment if you were to observe them defending their young (see image 7). The female carefully glues her eggs to the stems of underwater plants, and the male remains close by, defending them with great ferocity. No other insect we have discussed plays such a great role in the rearing of its young. In other water scorpion species around the world, the female lays her eggs directly on the male’s back! He must then continue to move around, supplying them with fresh oxygen, and keeping them away from predators. It is rare in the insect world that the males play such an important role in raising their young. We often consider insects in general to be unfeeling, and very distant from us. However, when we look at how they treat one another, we can see care being taken that we may relate to. The fierce water scorpion is a formidable hunter, but when taking care of its family, it can be as caring as humans are with their children.

Image 7
A young water scorpion. (*Belostoma americanum).* Notice how it’s wings have not yet developed.

Gentle Grazers and Other Gluttons

Predators are an important part of any ecosystem. By feeding on the sick or weak, predators make sure that the populations of their prey don't get too large. Without insect predators, many aquatic systems would not be able to function. However, the other important part of a healthy and happy ecosystem is the presence of *grazers.* Grazers feed on, or *graze,* plants and algae. You're probably already familiar with a common terrestrial grazer: cattle. Aquatic insect grazers are very important, because they keep underwater plant life in check, and prevent algal growth from taking over an aquatic habitat. Aquatic beetles that aren't predators are often referred to as *scavenger beetles*. These beetles dig into the sediment and eat rotting leaves and other plant parts that lay around the bottom of the muck. They usually have thicker bodies and no bristles on their legs, as they don't spend much time actually swimming, they simply root around in the muddy banks in wetlands and rivers. The muddy bottoms of rivers and ponds are excellent places to find an incredible amount of other fascinating aquatic grazers, which may not even be visible from above.

Image 8
A caddisfly larva outside of its case. The case is made of spirally arranged plant stems. Notice the hair-like gills around the larva's body. (*Limnephilidae sp.*)

These bottom dwellers are usually larvae of insects that transform, or *metamorphose,* into winged adults. Recall from Unit One that we briefly discussed how dragonfly larvae are found in wetlands before they crawl out on an overhanging piece of vegetation, and moult their old skin to emerge with wings fully formed before finally flying away. But there are others who occupy the bottoms of freshwater rivers and ponds too, most of them are much smaller than most dragonfly or damselfly larvae, but their roles in the maintenance of the water body are extremely important. They are remarkably well hidden among the plant and earth debris on wetland and river bottoms. These furtive insects are caddisfly larvae, building their homes using silk and carefully selected plant materials from their surroundings (see Image 8). They look like small pale grubs, often with a head that is covered by a hard plate. Sometimes they have patterned bodies, speckled with dark and lighter colours. Most often though, they are a pale cream colour, with six dark legs poking up from above their carefully built home. They use their legs to drag themselves around the wetland or river bottom, or to cling to plants or fallen logs as they search for food to eat. Incredibly, each caddisfly species makes an entirely differently shaped home, and entomologists can often tell a great deal about the species by looking at the construction materials and shape of this insect house.

The variation in architecture is astounding. One species of caddisfly larvae even constructs its humble home to resemble a snail shell, by "gluing" tiny grains of sand together into a spirally arranged pattern. Others make perfectly four-sided homes out of tiny fragments of wood, like miniature tubular log cabins. There is even a tiny species of caddisfly found in some Canadian rivers that fastens a pine needle or small fragment of twig to the top of its rounded home and uses it as a battering ram to plough its way through debris. Gently skimming a net along the bottom of a wetland or river can quickly yield some specimens of caddisflies to examine. Their architectural feats are truly another marvel of the insect world. And these are the mere larvae of adult caddisflies. Once they have grown to a certain size they form a cocoon, similar to caterpillars, by sealing the entrance to their pre-built home, and *metamorphose*, emerging from the water's surface as a beautiful, winged insect.

Besides their fantastically built houses, caddisflies have another adaptation unique to wetland bottom dwellers. They have *gills* that allow them to reside underwater for the entire duration of their larval life. Gills are specialized structures that absorb oxygen from the water. But their gills are very different from those of fish, which you may have observed before. Caddisflies breathe through gills that line the sides of their bodies. They look like stray strands all over their abdomens, as though all the larvae were wearing frayed sweaters. The ability to breathe through specialized gills, and build retreats, make caddisflies very well adapted to living the lives of an aquatic bottom dweller and they, along with the aquatic beetles and water scorpions, help comprise part of the incredible insect diversity that composes the still and moving waters of Canada.

We now understand that wetlands require predators and grazers to maintain a healthy habitat where many creatures can continue to grow and thrive. We have looked at the remarkable adaptations predators have to chase or ambush their prey, and the equally remarkable survival techniques some grazers have to blend in with their surroundings and remain living underwater. We have not however, examined a very important group of aquatic insects that are often present in the fast flowing waters of Canada's streams.

The *filter feeders* are a group of insect larvae that grow up firmly attached to rocks or plant debris in flowing waters. They are unlike the predators or grazers we have discussed so far because they do not seek out their food. Instead, they simply sway in the water current waiting for their food to come to them, at which point they carefully pluck it from the stream and eat it. They do this by filtering water through outstretched fan-like pieces protruding from their heads. These fans catch any juicy particles of food that may be flowing by in the current. Occasionally the larva will tuck the fans downwards into its mouth, nibbling off any food that may be present, before shooting them outwards again, and waiting for a fresh meal to appear.

Filter feeding larvae also transform with age. Many of them belong to the fly family, and black flies in particular are very frequent filter feeders inhabiting streams. Blackfly larvae in streams may be so numerous that they blanket the bottom and any fallen logs or rocks that may also be found there, forming a dense, waving, dark mat. Once they emerge from their watery birthplace as adult flies in great numbers, they can wreak havoc on any passing mammal. They feed on blood, much like mosquitoes, and in some parts of Canada have even caused the relocation of herds of cows in an attempt to prevent stress of blackfly bites from affecting the cows health.

However bothersome blackflies are to humans or many mammals, they serve a role as an important source of food for a significant number of bird species. Many migrating birds depend on insect **swarms**, such as those formed by blackflies, to replenish their energy. So we cannot discredit the importance of even the most aggressively irritating insects, as many other beautiful creatures that rely on their numbers for food would follow their disappearance.

Sometimes insects are pests to humans directly, acting as bloodsuckers that feed off of us. Other insects are pests to humans indirectly. They do not feed off of us, but rather destroy our sources of food if left to their own devices. The following section will discuss how we are continuing to learn about coexisting with insects, and the challenges we pose to one another.

Case Study – Walking on Water, Science or Magic Trick? The Incredible Water Striders

Water striders have taken unique adaptations to their habitat to a whole new level – or should I say, a whole new water level. These bugs (true bugs, belonging to Order: *Hemiptera* – see Unit One) can be found in the most unlikely of places – gliding along the surface of the water. They can move at unbelievable speeds, most often across still water, but occasionally over slow flowing water also. They can be solitary or numbering in the dozens depending on the species. Each species has an elongated, oval, dark body with six very long, slender legs. How do these insects skate so easily across the water surface, or even sit still, allowing themselves to be carried by the surface current for periods of time, without falling beneath the water surface? They use the *surface tension* of the water to their benefit. Surface tension results from the ability of water molecules to stick together through attractive forces. This forms a very thin film-like layer on the surface of the water that the water striders are able to "walk" on. The legs of the water striders are very long and spread out from their bodies. This helps distribute their weight, so that not all of their body weight is in one place. This helps in preventing the water strider from breaking the surface tension, and falling beneath the water surface. In fact, should a water strider ever get caught out in a rainstorm, or become submerged for any reason, its body *still* would not sink below the water surface. Water striders are covered in *minute* hairs. Should any water fall on a water strider's body, instead of getting wet, these tiny hairs would trap air keeping the insect dry. This even helps the water strider float back to the surface immediately if it were to submerge – like an insect version of inflatable water wings.

As we have seen, there is a scientific explanation to why water striders are capable of living so successfully by striding across the surface of the water. However, if you are lucky enough to find one on a body of water, you will certainly agree that it truly does look like a magic act.

Worlds Collide – Coexisting With Insects

Throughout this reference book, we have focused on insects in their natural habitats: forests, wetlands, rivers, lakes, etc. But if you look carefully, you can find insects just about anywhere, even in your home. A significant number of insects live in our cities and agricultural areas and, believe it or not, we should be very grateful that they do. This unit will explain why.

Insects in Cities

Urban areas can provide a home for many of the species we have already discussed. However, the roles of insects in urban environments can be perceived differently than their roles in the wilderness. Whereas ants often function as important aerators of soil, or officers of seed dispersal, in urban and suburban areas we tend to regard them as pests, destroying our manicured lawns or venturing too far into our homes as unwanted guests. Many flying insects are also regarded as pests. Mosquitoes and houseflies are particularly troublesome, having the reputation of spreaders of disease. Houseflies typically feed on rotting meat or animal waste. As they land on our food to sop up juices from what we are about to eat, they can spread salmonella or other foul bacteria that can cause illness in humans. Mosquitoes can carry diseases from person to person (for example, the microorganism that causes malaria), or from animals to people, (for example, West Nile virus) as they suck blood from multiple sources, or hosts. Perhaps the most notorious are the stinging insects, namely bees and wasps, which many of us regard with outright fear. We take great measures to carefully destroy wasp or bee nests, or prevent their establishment in the first place. In urban areas humans are openly in the midst of a war with insects. However, having learned about the importance of all of these different kinds of species, we can perhaps begin to understand the importance of striking a balance between regard for human life and the wellbeing of our six-legged friends. Though they may often seem like pests to us, these creatures are valuable to urban ecosystems, and without them our lives could be unimaginably different than they are today.

Consider ants, for example. In urban areas they are still vital sources of food for predators, such as birds or even localized populations of amphibians. They remove plant waste from our landscapes and help the spread of seeds. Although anthills may seem unsightly on our lawns, they provide an important service for our soils by bringing air to the roots of plants, allowing for better plant growth. Instead of ridding your home entirely of ants, try to manage them. If you do not want them indoors, be careful not to leave sources of food out for them (anything with a high sugar content often acts as an ant attractant), and they will leave your home alone. Encourage the practice of leaving some anthills in an area where they might otherwise be eliminated. Consider their important role in the environment as described above and in Unit One.

Houseflies and mosquitoes are also vital sources of food for birds and amphibians, as well as bats and even other insects. It is appropriate to keep flies away from your food by covering up your meals, or avoiding areas of dense fly populations. However, remembering their role as a food source will help you understand and defend their presence on the landscape. If they should disappear, many bird, amphibian and bat species would fade or altogether vanish from the urban landscape, for lack of a food source. The case of the mosquito is similar. It is important to keep mosquito populations under control in urban areas to prevent the spread of diseases, such as those caused by the West Nile virus. This can be achieved simply by preventing puddles of water forming in old tires, flowerpots, ponds or other common places that may contain still water ideal for mosquitoes to lay their eggs on. However the presence of some mosquitoes is important. Adult mosquitoes serve as an important food source for small birds and amphibians, and also damselflies and dragonflies. Recall that mosquito larvae are aquatic, and serve as a food source for another range of wildlife, including shorebirds, amphibian larvae such as tadpoles or young salamanders, and fish. What we perceive as a pest is actually another vital component of a habitat of creatures, or ecosystem.

The Curious Case of the Cockroach

Insects that are the most problematic in urban areas are often not native to those areas. Non-native insects, or insects that do not naturally occur in a region but have established themselves there, are called *invasive species.* In most cities around Canada, the best example of such an insect is the infamous cockroach. Cockroaches belong to their own order (*Blattodea*), and are distinct from beetles or true bugs due to their flattened bodies, unique fast method of running, long antennae and, most importantly, hairy legs. The reason cockroaches may be so hard to spot (unless of course their numbers are incredibly large and they run out of places to hide) is because they are incredibly sensitive to the approach of potential predators. Their legs are covered in minute hairs that are very sensitive to vibrations from the ground, announcing the approach of another organism. This, coupled with their flattened body shape and lightning fast *reflexes*, allows them to effectively hide in a tiny space before we’ve even had a chance to spot them.

Being so adapted to hiding from predators, as well as the ability to rapidly reproduce and survive harsh conditions (as long as they have a source of heat, easily found in human homes) has allowed cockroaches to thrive in urban areas, even if their origins are thousands of kilometres away. Entomologists theorize that most Canadian cockroach populations are actually of European descent. It is likely that at the time that Canada was being colonized by European settlers, these clever beasties hitched rides on cargo ships and rode across the ocean into port cities, and spreading in luggage and personal belongings of settlers moving across the country from there. In small numbers, cockroaches are relatively harmless. They do not sting or bite, and have become another food source for animals quick enough to catch them. In large numbers however, they can also spread diseases, and even cause allergic reactions in more sensitive individuals. This is again where we must understand how to strike a balance with insects in our surroundings: lowering the amount of food present for them to eat or lowering the quality of adequate breeding conditions, thereby keeping their numbers down. In extreme cases, extermination is an appropriate answer, where a large population is destroyed in the interest of keeping the human population safe from adverse health effects such as diseases.

However, another important lesson must be learned from the example provided by cockroaches. Careless human activity leading to the spread of accidental introduction of non-native species can lead to very serious problems. We must learn from these mistakes, and be careful to avoid bringing new species into new areas when we travel. Having learned the importance of insects as important components of their natural habitats, we now know it's important to not disturb these habitats. Sometimes however, disturbance is necessary to promote human well-being. In other words, sometimes humans need to make changes to the landscape, affecting insects and other wildlife in order to help humans survive. We will discuss an example of such a situation at length in the following section.

Pollinators and Pests – The Agricultural Landscape

At the time this reference book was written, the human population in Canada was 34.5 million people. That's a lot of people that need to be fed! Human populations are mostly sustained through agricultural development. Perhaps you live in an area like the Prairies where much of the land has been converted for agriculture. You're probably aware that important food crops like wheat, canola and legumes are grown. Or, if you live in the fruit producing regions of British Columbia, you've likely seen the cherry, apple and peach orchards. To produce enough food to feed the population of Canada, as well as export some of the food elsewhere in the world, an abundance of crops must be nourished and looked after by caring farmers.

Fortunately, farmers producing some crops get an important source of help from an unlikely group of animals – insects! This is because some insects are important *pollinators*. A pollinator is an animal that serves to move pollen from one flower to another. Pollen is involved in the fertilization of some plants, resulting in the production of a fruit from that flower. In the case of some crops that are grown for their fruit (apples, cherries, nuts, soybeans, tomatoes and others), the importance of pollinators can't be overemphasized. By helping pollinate these kinds of crops, insects perform a very important service that helps farmers produce more food. In fact, without pollinators, humans wouldn't be able to produce enough food to survive. We'll discuss the most important group of insect pollinators later in this section.

Unfortunately, there are also insect pests in agricultural areas, much like there are in urban areas, except wide expanses of potential food sources mean that pest populations of insects can grow to incredible numbers. There are a wide variety of insects that are considered pests to agricultural crops because they thrive very quickly in agricultural fields and are capable of destroying large amounts of the plants produced on the land. The type of pest present is largely specific to the crop being produced. Aphids are tiny green bugs, with or without little clear wings, that are often found on the undersides of leaves or surrounding newly formed leaves or flowers. Aphids are common on crops such as canola, and weaken plants by sucking out their nourishing juices. Many species of butterflies or moths have caterpillars that prefer crop plants as sources of food as well. The Cabbage White butterfly, for example, favours cabbage leaves as a caterpillar, and can eat enormous quantities of these leaves in a short amount of time. Finally, perhaps one of the largest and most well-known of the crop pests is the grasshopper. Under the right conditions (usually hot and dry summers) their numbers can swell up into the millions and form swarms. Because they are voracious consumers of plant material, and there can be millions of them, grasshoppers can easily devastate cereal crops and destroy plant life wherever they go.

The most effective way of reducing or nearly eliminating insect populations in an agricultural area is to apply an *insecticide.* Insecticides poison insect populations, thus protecting the plant species that the farmers want to *cultivate*, or grow on the landscape. This in turn, allows for a large enough amount of food to be produced on the land and distributed to cities, towns and rural communities. Controlling insect pests is extremely important for the continued survival of human populations.

Unfortunately however, the insecticides many farmers use do not discriminate between "good" insects like pollinators, or "bad" insects that are pests. This is an important drawback of insecticides, and farmers must balance the benefit of reducing pests against the cost of killing the important pollinators. In fact, insecticides have caused populations of many beneficial pollinators to drop, or even disappear from some areas. The most notable case is described in the following Case Study. The death of pollinator populations can have important economic impacts to farmers. One way that farmers have managed to avoid this unwanted side-effect is to manage pest populations using wasps. That's right, using insects to combat other

Image 9
An example of an area in Central Saskatchewan heavily influenced by agriculture. Canola is the crop type pictured here, and the yellow flowers can attract a large amount of insects.

insects. Remember how we discussed that some species of wasps are parasitic? Farmers have used this to their advantage by promoting or deliberately releasing particular wasp species that parasitize agricultural pest insects. Because the wasps ultimately kill their hosts, they help reduce the pest insect populations. While sometimes not as fast-acting as chemical insecticides, this kind of biological pest management is more environmentally friendly because it reduces the impact to pollinators and other non-target insect species.

Case Study – The Disappearing Act of The Honeybees

Some of the busiest, hardest working, and most agriculturally important insects are the honeybees. These fuzzy, brightly coloured creatures spend their days buzzing from flower to flower, collecting nectar and pollen from plants to carry back to their colonies in an effort to support themselves and the other bees they live with. Bees have been observed performing some extraordinary behaviour, and are recognized as highly intelligent, social and organized animals.

As mentioned, bees work and live together in a colony. Colonies are built in areas with favourable conditions, for example, old houses or piles of wood, maybe even underground or in an old log. These areas are safe from most predators, protected from wind and rain, and most importantly, located fairly close to a plentiful food source. Bee colonies begin in much the same way that ant colonies begin (remember, ants and bees are close relatives). A fertile female bee (called a *queen*) will find the perfect place to start building her empire, laying eggs that hatch into *worker bees* (infertile female bees) or *drones* (male bees). A bee colony is constructed from a thick, waxy material called *honeycomb* or *beeswax*, strategically deposited in a complex pattern by members of that colony. The honeycomb is made of *hexagonal* (six sided) holes, or *cells*. These cells are used for the deposition of eggs or storage of food. Bee food is, of course, sweet and delicious honey. Honey is produced from partially digested pollen and nectar that the bees eat while visiting flowers and then deposit into the cells upon their return to the colony. The honeycomb itself is also made from a type of honey that was digested differently by the bees, and so has a tougher texture than the liquid honey stored within the cells.

Coordinating such a large population of individuals is an incredibly daunting task. How is it possible then, that bees are so efficient at finding sources of food, and collecting enough nectar and pollen to feed the entire colony, as well as successfully caring for young bees as they develop? Their secret is an amazing method of communication. Entomologists have observed that certain movements that bees make signal instructions to other bees. As a general example, a bee may spin left or right, flap its wings a certain way and vibrate its body. This sequence of movements may inform the bees watching of a message, perhaps “Follow me, there’s food this way!” This ability to communicate, coupled with an inborn sense of duty (like ants, bees are born into their roles, which they will continue to carry out for the remainder of their lives), makes bees exceptionally productive insects.

Honeybees can establish empires, look after one another, communicate with one another, produce honey and pollinate flowers. They are fascinating to learn about and watch from a distance (remember, bees have a stinger that delivers a very painful wound when the bee is agitated, so never attempt to handle a bee.) and they provide humans with an incredibly important service. Unfortunately, bee populations worldwide are in rapid decline. Why? Because the bees are disappearing. There are many reasons why this may be occurring. A parasitic mite (a tiny, eight-legged creature) has been considered partly to blame. The mite, *Varroa destructor*, attacks honeybees, spreading rapidly throughout entire colonies, wiping out the workers, causing food supplies to dwindle and forcing the remaining colony population to perish. In addition to the mite infestations observed, a nasty fungus has also been attacking bee colonies, working in a similar way by stressing and killing bees within their colonies causing the colonies to collapse. The final stroke of misfortune comes from humans. Some agricultural practices have caused significant stress for honeybees by exposing them to harsh chemicals (such as the insecticides mentioned above) or changes in the landscape that affect their colonies.

If honeybees were to disappear from our landscapes, agriculture production of many crops would be greatly reduced. The fruits and vegetables we farm that rely on visits from pollinators to be productive would suffer. Not only would this cause economic problems for the farmers who make a living growing food, but it would cause very big problems for the human population relying on this food for survival. It is in our best interest to learn about the habits of the bees, to understand how our actions affect their populations, and how we can improve how we grow and gather our food from crops, to lessen our effect on their populations.

Conclusion

We share the world with many, many insects (and other animals), so entomology is of enormous importance in understanding how the world works. As we have seen, insects are an important part of any habitat, are food for other animals and perform essential ecosystem services. In fact, if all the insects disappeared from the earth, our ecosystems would crumble and collapse. Waste would build up on the landscape, many plants could not effectively reproduce and many animals would be left without a source of food. We humans wouldn't be able to escape this effect – after a very short period of time we'd be left without resources. Life as we know it could not continue. So remember, insects deserve our respect. It is up to you to learn how to pay closer attention to the world around your feet and buzzing amidst the flowers. By learning about and respecting the other life forms that inhabit our planet, we can learn how best to coexist and thrive together. After all, the miniature world of insects that we are surrounded by mirrors the "human sized" world we ourselves are born into. If we cannot take good care of it, what will that mean for us?

Glossary of Common Terms

Adaptation: a unique skill or character of a species that allows it to be better suited to its particular environment

Example: Diving beetles have a special leg shape and swimming hairs on their legs to help them swim faster in their *aquatic* environment.

Aerial: ‘in the air’ – referring to insects that are capable of flight

Example: Flies, Wasps, Bees, Dragonflies, Damselflies and Butterflies are all examples of aerial insects, as they spend **most** of their time flying around.

Aquatic: referring to insects or animals that inhabit water-based habitats. These creatures spend the majority of their time underwater

Example: diving beetles, dragonfly larvae, caddisfly larvae and many more!

Camouflage: some insects resemble their surroundings because they have the same coloration or texture as their habitat. This allows them to hide from their predators, even if they’re in plain view.

Example: Dragonfly larvae can actually change their colours very gradually (with every moult) to more closely resemble the colour and texture of the substrate they inhabit, and so are more hidden from predators.

Carnivore: an insect or animal that survives by eating other animals

Example: A water scorpion is a carnivore.

Colony: A population of the same species of insects living together in a structure they built together

Example: An anthill is an example of an ant colony.

Common Name: the term adopted for an insect group or insect species by people of that region. Common names may be easier for some people to remember, however because the same species may have a different name depending where in the world you go, it is easier to use and remember the specific *scientific name,* which is accepted all over the world for that species or group of insects.

Example: Monarch butterfly is the common name for *Danaus plexippus.*

Entomologist: A scientist who specializes in the field of studying insects

Example: Jean-Henri Fabre (1823-1915) is a famous French entomologist who wrote many books about insect behaviour and *morphology*. His books are easily accessible to all reading levels, and are highly recommended for beginner entomologists.

Exoskeleton: a rigid structure composed mostly of *chitin* that provides the shape for all *invertebrates*. You can think of it as an outer skeleton

Example: All invertebrates (crustaceans – crabs, shrimp… and hexapods – insects… etc.) have an exoskeleton.

Habitat: an area that meets a certain amount of characteristics that a particular group, or groups, of insects find favourable

Example: A meadow is the perfect habitat for butterflies to flourish, as here they can find plenty of food, other butterflies and many places to lay their eggs and begin a new generation of butterflies.

Hexapod: a creature with six legs

Example: an insect

Herbivore: an insect or animal that survives by feeding on plants or fungi

Example: A butterfly is an herbivore.

Larva (plural is **Larvae**): The young stages of an insect that do not resemble the adult stage because they are not fully formed

Example: A mosquito begins its life as a larva in an aquatic environment, then *moults* into the winged adult form.

Leaf Litter: the layer of leaves and dead plants on the ground. Often many different type of fungi grow here, providing food for some insects. Other insects feed on the insects that feed on the fungi. This is an example of a *food chain*.

Example: Ground beetles and ants look for food in the leaf litter. Most ants collect decaying plant parts and fungi, and many beetles are *carnivores*, feeding on ants and other small creatures in the leaf litter.

Moult: the process by which insects remove their old exoskeleton, emerging larger, or with a different set of body characteristics (i.e. with wings). Insects do this because their hard exoskeleton does not grow with them, like our skin does. The insect instead keeps growing *within* the exoskeleton, until it finally outgrows its old skin and emerges as something new.

Example: A dragonfly larva will moult several times over the course of its life to grow, then to develop wings as an adult.

Morphology: the body plan of an insect or animal

Example: A butterfly has a very different body plan than a beetle, thus they have very different *morphologies.*

Nectar: the sugary liquid produced by flowers to attract insect pollinators

Example: Look at a flower and see if you can spot any tiny gooey drop of sticky nectar inside.

Nocturnal: an insect or animal that is most active at night

Example: Most moth species are most active at night. Fireflies are also an example of a nocturnal insect.

Rostrum: The special sharp, short, straw-like sucking mouthparts of the "true bugs" (*Order Hemiptera*). These mouthparts can be used to suck up the body fluids from prey, or the juices of plants.

Example: A water scorpion has a rostrum it uses to suck juices from its prey, whereas an aphid has a rostrum which it uses to suck juices from plants.

Scientific Name: the Latin name given to a species, family or Order. Scientific names are important because while *common names* may vary from place to place, every scientist in the world uses the same Latin name for a species.

Example: We can call aquatic beetles diving beetles, predacious diving beetles or water beetles. Different people in different places may use any of these different names but scientists use just the one name for them, Dytiscidae, and so prevent confusion.

Semi-Aquatic: insects or animals that spend only a small part of their life in water, and the other part of their life on land

Example: Water striders are considered semi-aquatic as they live their lives close to, but not actually in the water.

Species Diversity: variation in the amount of species present

Example: A wetland has large species diversity, because there are many different kinds of insect species that inhabit it.

Swarm: an immensely large group

Example: Black flies or grasshoppers will congregate in swarms when conditions for reproduction are ideal.

Terrestrial: a land, or "dry" environment, as opposed to an aquatic environment found in lakes and rivers

Example: Forests, deserts and grasslands are all examples of terrestrial habitats.

Vegetation: the types of plants present in an area

Example: A forest has a lot of tree-type vegetation, where as a grassland is mostly comprised of grass-type vegetation.

Wing Venation: the pattern created by the supporting veins in the wings of insects. The patterns made by these veins are very specific to different species, and so are important to notice so they can be used later on for identification purposes.

Example: Image 2 in Unit Three is a picture of dragonfly wing venation.

Suggested Resources

For research on prairie aquatic insects: http://www.aquatax.ca/

The BBC Life in the Undergrowth (2005.) Television series, presented by David Attenborough

For general research – The Entomological Society of Canada: http://www.esc-sec.ca/

To browse an entomology collection: http://www.entomology.ualberta.ca/

For junior entomologists: http://simplekids.net/junior-entomlogist/

Insect collecting for junior entomologists: http://www.bedbugs.org/insect-collecting-for-kids/

Information on rearing and raising your own butterflies and moths:
lancaster.unl.edu/nebline/2001/jun01/page3.pdf

How to build a pitfall trap: http://tlc.howstuffworks.com/family/easy-outdoor-activities-for-kids5.htm

A good website to scout out tools for catching insects, or where to buy a handy entomology field guide: http://www.bioquip.com/

List of insect species in Canada: http://canadianbiodiversity.mcgill.ca/english/species/index.htm

Facts about butterflies:
http://www.enchantedlearning.com/subjects/butterfly/allabout/Extremes.shtm

Weird insects: http://www.squidoo.com/really-weird-insects

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