Insects Good & Bad

By Tim Braun

Introduction

There are two sides to almost all agricultural pest control problems. This three-hour course will discuss predator insects along with insect pests. From how these insects grow, feed, and multiply working with us and working against us. Insects have proven their place in agriculture both as detrimental and useful. In some cases, the insect can help in the production of agriculture or within its short lifetime become a powerful pest of agriculture. Some insects spend their entire lifetime as pests or as predators of pests and others can work both sides of the street as a pest or as a predator of pests during their lifetime.

My first boss after I graduated from college was a pretty good entomologist. One day he took me with him to a grape vineyard in Delano, California where a large table grape grower had a fruit fly infestation. The table grape vineyard had a large infestation of fruit fly and the grower was getting close to harvest. My boss decided the only thing to do was to apply three applications of a pesticide in three day intervals. He explained to me that fruit flies go through a life cycle that includes: an egg stage, a worm or crawling stage, a pupa stage, and an adult stage. He said that the pesticide would kill the worms and the adults, and that the adults mate and lay eggs within thirty hours after coming out of their pupa stage. Eggs hatch within one day the worms last four days and the pupa stage lasts and additional four days. By spraying three applications in a period of six days during daylight hours when the fruit fly was active he hoped to cover all susceptible stages of the life cycle which included worms and adults. During the ideal conditions that existed at that time of year, the longest stage (pupa) was four days and so was the worm stage. The sprays would have seven-day duration with the last spray lasting about a day. Adults are exposed to every spray. Crawlers are exposed to every spray. Eggs are safe for a day and pupa is safe for four days. This method of insect control worked superbly in this case and it pointed out the need for a good knowledgeable background in insects.

Later in 1975, I ended up in Yuma, Arizona. I had a situation with a pink boll worm infestation in Pima cotton. The worm count in the young cotton bolls was very high in a field that a grower asked me to check. I used a parathion form of pesticide and in this case I used three applications in five day intervals over a period of eleven days with applications at night. The field of cotton unlike the grape vineyard wouldn't be harvested for at least two months. I was able to use a chemical with a longer life that attacked the same enzyme in the insect 's body that had killed the fruit fly. The results were good and we went to our regular weekly boll checking followed by applications based on infestations for the rest of the season and the grower ended up with a good yield.

The pesticide used for the fruit fly application control was called TEPP (Tetraethyl Pyrophosphate). This insecticide works on the nervous system of the insect and it works at a very rapid pace. Unlike other phosphate insecticides like parathion which was a very heavily used insecticide in those days, TEPP works much faster and produces more kill in six days with three applications. TEPP has oxygen in the molecule allowing the insecticide to do its job immediately. The parathion has sulfur in its molecule that must be replaced by oxygen to be effective and this requires time.

Pink bollworm has a slower timed life cycle and requires follow up applications after checking for the larva stages of growth. Both insecticides act on the living insect's enzyme called acetylcholinesterase. This enzyme is from a group of enzymes called cholinesterase in animal bodies (which includes insects). This animal's enzyme has the job of stopping chemicals that cause the activated neuron to stop activity and go into a resting stage. "Neurons" are

classified as cells that carry out impulse conducting. These include: the brain, the spinal column and nerves. Without the action of this enzyme the neuron, once it starts, it will continue reacting causing serious damage and the death of the insect. So if we can tie up the insect's needed enzyme with our pesticide (the insect's inhibitor) we allow the insect's own over-active neuron to kill the insect.

The company I was associated with in Arizona had crop dusting planes. We had to check the pilot's eyes periodically when they were applying these pesticides. We could tell when they had absorbed some of the pesticide by checking the pupils of their eyes. They worked at night and we'd stop them from working to see if there was any change in their eye pupils. We also had the workers doing pesticide mixing and loading submit blood samples to monitor their uptake of any of the pesticides that they handled.

Insect pest control has changed considerably. We now have pest control methods that are more sophisticated. The study of how insects survive has developed insecticides like growth regulators that control specific insect pests by stopping stages in the insect's life cycles. We have crops that carry a specific control material that specifically kills the insect pest that consumes the crop. Working with knowledge of the insect and its methods of growth has replaced some of the need for insecticides that are harmful to us. The use of insect traps baited with insect pheromones has allowed us to live with insect infestations that do not require unneeded applications of pesticides. Knowing how insects multiply, exist in the weather we have and move about this planet has given us methods and time to lessen the effects of insect problems. These methods of dealing with insects require an in-depth study of how the insect lives and which ones are the problems and which ones require control methods. The use of insect predators for insect pest control has become a line of agricultural business along with pesticides. Insect pest control is a changing job that requires knowledge and training.

Insect Classification

The scientific classification of insects explains that we have kingdoms: Insects are in the "Animal Kingdom", in the "Arthropod Phylum" and the "Insect Class". Now, these definitions can be used, but classifications change constantly as research improves.

Animals in the Arthropod Phylum and the Class "Insects" have a body that unlike other animals has an exoskeleton that supports their body just as the internal skeletons support the other animal bodies.

The exoskeleton not only provides support to the insect's body, but it also protects the body from external harm. The exoskeleton protecting the insect's body is made up of a material called chitin. Chitin is a pliable, tough and translucent material that allows light to penetrate it. This skeleton covers the outside of the body; therefore, to grow larger, the arthropod phylum of animals shed their exoskeletons and grows larger ones during their lifetime.

The Latin word, *insecta*, means "animal with a divided body" or cut up (notched). The word was used back in the sixteen hundred. Aristotle used this term to describe the insect's notched bodies. The adult insect's body consists of three parts: the head, the thorax and the abdomen. This body has three sets of legs located on the body's thorax or mid-section. These legs of the insect are jointed. Their eyes are located on their head along with one pair of antennae. The numbers of known insects are enormous with over a million species. Of the known living organisms on the earth, insects make up more than half of all of them. On land where most of the insects are found they represent over ninety percent of the individual animal

life forms. Another similar arthropod group, the crustaceans, dominates the oceans. There are three arthropod groups: arachnids, insects and crustaceans. Spiders represent the arachnids.

Chromosomes

What is the most important part of a living body? The living cell which is found throughout the animal body is probably the most important part of the living insect body. This three-hour course is about insects and insects which are animals with living cells. Most of the living bodies start out as a cell. Cells are found throughout the living bodies. Cells are often called the building blocks of life and inside the cell are the chromosomes. Chromosomes are made up of proteins, DNA and RNA.

The DNA has a long name, Deoxyribonucleic acid and it can be found in all our cells that are found in sweat, saliva, blood and many other parts and liquids of the body. Detectives use it to locate murderers. DNAs are different and their differences are used to identify the living individuals and even the dead. DNA is made up of genes. These are features or traits that are passed on to the offspring of living organisms. They include eye color, height, weight and other things contained in a living object. Genes can also carry the resistance to various diseases and blood types. Some of these genes are activated by weather and other different conditions that the living organisms exist in. The DNA activates the instructions contained in the genes. These actions can make needed parts of the body and unneeded parts like the dreaded cancers.

The chromosomes are made up of DNA, RNA and proteins. The RNA is a smaller chain of molecules than the DNA. RNA is Ribonucleic acid that regulates information given by the genes that is used in building proteins. Proteins are made from amino acids. RNA gets its information from the chromosome. RNA moves about the cell building proteins using the gene messages that are instructions on how to build these proteins. RNA is described as factories that build proteins.

The chromosomes are located inside the nuclear area of the cell. The insect or animal cell has a nuclear membrane that contains the chromosomes and this nuclear part of the cell is inside the fluid of the cell. The insect cell itself is covered with a cell membrane. Plants have a cell wall instead of a cell membrane which is also used for the plant's support.

The chromosome may be circular like a cushion spring or stretched out in a linear position. In most of the living cells the chromosomes are in pairs. In human cells there are 46 chromosomes: (twenty three pairs of chromosomes). Fruit flies have 8 chromosomes. Cats have 38. Rabbits have 44. Gorillas have 48. Half of the chromosomes come from the mother and half come from the father. Sex cells like unfertilized eggs or sperm have single chromosomes. Sex cells with single cells are called *haploid* cells and all the other cells with pairs of chromosomes are called *diploid* cells.

The chromosome pairs are joined together at an area on the chromosomes called their centromere.

The centromere may be in the center or close to the top or the bottom of the joined pair of chromosomes.

They then have so called arms that can wave around the centromere that holds them together.

Insects grow like all other animals by enlarging their cells with the available food and water or by duplicating their cells. When they are embryos, they grow by duplicating their pairs of chromosomes forming four or a foursome of chromosomes. The foursome is stuck together in their centremere area. The foursome of chromosomes is then pulled apart forming two pairs of chromosomes. Then nuclear membranes are formed around the pairs of chromosomes inside

the cell. Then the cell membranes grow around the pairs of chromosomes inside their nuclear membranes and we have two new complete cells from the old original cell and a bigger insect.

Insects during their life go through life stages. During the nymph and larva stages insects grow by consuming food. During this growth stage, they do not grow by duplicating their cells like they did when they were embryos. During the pupa stage of life that some insects go through, the growth is done by duplication of the insect's cells. Even the insects that do not have a pupa stage will activate the cells that they carried with them through their nymph or larva stages and these cells will duplicate themselves. These cells carried from the egg stage are called imaginal cells or discs. This allows them to grow into adults with wings, sex organs and other parts of the adult body. Adult insects do not duplicate or double their chromosomes once they reach full adulthood. Their chromosomes and cells do carry on maintenance of their existing cells until death.

Mitosis

The growth that occurs by duplicating the chromosomes is called mitosis. To form new cells the chromosomes must duplicate themselves. Then new nuclear areas with membranes form around them and the cell itself is covered with a cell membrane and we have a new identical cell. This occurs for insects and other animals, but plants form cell walls around their cells instead of cell membranes. Plants that do not have skeletons either external or internal need the cell walls for structure and protection.

Insects and other animals go through a series of steps to form their new cells by a process called mitosis. This process begins with the pairs of chromosomes giving instructions from their DNA to their RNAs to produce new proteins that are needed in the mitosis process. Once they have enough proteins to support the mitosis process the pair of chromosomes reproduces themselves. We know the double the number of combined pairs of chromosomes and these pairs are joined together at their centromeres. When you have a group of pairs of chromosomes joined together at their centromeres it is like the pompoms that yell leaders wave around only these pompoms aren't joined together at their mid points. The top strips may be shorter that the bottom strips, but the chromosomes still have long enough strips of material to have the same effect as yell leader pompoms. We now have several foursomes of chromosomes.

The pulling apart of these two pairs of chromosomes that were produced when one pair doubled or duplicated themselves is called **mitosis.** Once the pairs of chromosomes duplicate themselves, the cell begins to changes. Inside the cell the nuclear membrane breaks down and disappears. The two connected pairs of chromosomes as well as all the other connected pairs of chromosomes are now in the cytoplasm of the cell. The nuclear membrane has gone. Two poles form on opposite sides of the cell. Attached to these poles are fibers that look like ropes. They are called spindle fibers. These spindle fibers extend from the poles at the sides of the cell near the cell membrane to the centromeres of all the combined pairs of chromosomes located at the center of the cell. (The number of pairs of joined chromosomes in each cell that are in the insects and other animals can vary by species.)

The spindle fibers grow from the poles at the sides of the cell to opposite sides of the two pairs of joined chromosomes in the middle of the cell. The ends of the fibers reach the centromeres where the pairs of chromosomes are connected. On the centromeres, there are sticky protein structures which the ends of the spindle fiber that are now pressing on stick to.

These sticky protein structures are called kinetochores. The fibers from each pole attach to each pair of chromosomes by sticking to these kinetochores.

The fibers that are connected to the poles on opposite sides of the cell membrane and stuck to each pair of chromosomes start shrinking. As these fibers shrink, they pull the pairs of chromosomes apart toward each pole that is located at either side of the cell. The cell grows longer. Once the pairs of chromosomes are apart and have been moved to the opposite ends of the longer cell, the poles and fibers break down and disappear. The middle of the cell membrane pinches together forming two diploid cells with pairs of chromosomes.

A new nuclear membrane forms around the pairs of chromosomes inside the cells. The chromosomes start giving out instructions from their genes and the mRNA carries the messages to the other RNA factories and the building of new proteins begins inside the cell. The cell may start another mitosis procedure immediately or the cell may go into a brief resting stage.

Insect larval and nymph cells can repair and do maintenance for their cells during their life, but they do not duplicate their chromosomes using mitosis during their larva and nymph stages. Larva and nymphs grow larger by consuming food and water not by increasing cell numbers through mitosis. Insects can also grow by mitosis during their pupa stage. Once their adult body parts are formed their mitosis activity ceases. Mammal cells carry on mitosis when they are juvenile and still maturing. Once mammals mature mitosis stops except for blood cell duplication in the bone marrow, in the lining of the digestive system and in skin cells that flake off. Mammals and insects existing cells will repair and maintain themselves until they die. This is another reason to keep fit by being active. Activity keeps chromosomes in shape and active.

Meiosis

For insects to multiply they have two methods: sexual or asexual. The sexual fertilization is the joining together of a cell with single chromosomes from the female with a cell with single chromosomes from the male. Sexual fertilization produces cells with pairs of chromosomes joined together at an area on each chromosome called the centromere. The male single cell chromosome cells are called sperm and the female single cell chromosome is called an egg or an ovum. Both cells, male and female are called gametes. Several insects can produce their young without fertilization. As an example, aphids use the asexual method when food is plentiful and conditions are okay but when conditions get tough they use sexual fertilization. Meiosis is how sex cells with single chromosomes are produced by insects. Mammals and plants go through the same procedure with some variations to produce cells that have single chromosomes for fertilization that also requires meiosis.

Meiosis is like mitosis, but it is divided into two operations instead of one. They are meiosis I and meiosis II. Meiosis is not called a cell cycle like mitosis that is ongoing and has a goal of increasing cell numbers for the growth of an insect. Meiosis has a goal of producing offspring with differences in their genes. As conditions change the insects that also changed have a better chance of surviving in the new conditions they live in.

Most of the chromosomes are in sets of joined pairs in the nuclear area of the cells of insects. One chromosome from the female and one from the male in each joined pair. These cells with chromosome pairs are called diploid cells. Meiosis is the process that the cells go through to produce fertility cells with single chromosomes called haploid cells instead of having pairs of chromosomes called diploid cells. Before the chromosomes enter the splitting stage the cell goes through a period of preparation. The chromosomes must duplicate themselves. The DNA activates the RNA to make more proteins to produce the building through duplication

of chromosomes. Each pair of chromosomes doubles itself by using the newly made proteins to duplicate the pairs of chromosomes. This gives us quartets of chromosomes two from the mother and two from the father. These four are joined together at their centromeres.

The next step is a process where the genes are passed from one chromosome to another. This is called crossing over of the genes. The chromosomes line up together sort of like kick lines with the pairs together with a lot of shaking going on. This allows the chromosomes to bump into each other and where they make contact genetic information is exchanged. These areas where they touch are called chiasmata. So, this passage of information changes the chromosome information of each chromosome. They are different and this difference will produce different insects.

The quartets of chromosomes move together as groups of four at the center of the cell. Each pair of chromosomes has sticky kinetochores attached to their bodies at their centromeres. There are two kinetochores one on either side of the joined pairs of chromosomes holding them together.

The nuclear membranes inside the cell membrane around the chromosomes break down. The chromosomes are inside the cell membrane's fluid in the center of the cell. The fibers are attached to poles on either side of the cell. The sticky kinetochores on the foursome of the chromosomes connect with the ends of the fibers. The fibers that are attached to the poles at one end of the cell and to the sticky kinetochores on the pair of homologous chromosomes that is attached to its pair of sister chromosome begin shrinking. This activity results in a split of one pair of the homologous chromosome with its sister chromosome from the other homologous chromosome and its sister chromosome.

All the chromosomes lose contact where they made contact at their chiasmata when a transfer and a mixing of genes among the chromosomes took place and their DNA changed.

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After the quartets of chromosomes have parted the poles and ropes dissolve. The cell membrane starts to pinch and grow together at the center of the cell. This results in the formation of **two** cells with pairs of chromosomes in each cell. The pairs consist of one homologous chromosome along with its duplicate sister chromosome in one cell and one homologous chromosome and its sister chromosome in the other cell. In both cells the poles and ropes are gone. The two joined chromosomes in each cell are joined at their centromeres inside a nuclear membrane.

In the two cells, we now have two chromosomes held together at their centromeres. The sticky kinetochores are fastened to the centromere location of the chromosomes and to the ends of the ropes which are attached to the poles located on each side of each cell's membrane. The ropes begin to shrink causing the chromosomes to pull apart and move to

either ends of the two cells. This activity takes place in both cells at the same time resulting in four single chromosomes.

The ropes and poles break down again and disappear. The cell membranes of both cells pinch and come together parting the two cells at the same time. This forms four cells with a single chromosome.

Inside each of the four cells nuclear membranes form around each chromosome which is now single chromosomes and the cells are now called haploid. These cells are sex cells for the insects. These cells are called gametes. If the insect is a male the cell is called sperm and if the insect is female the cell is called an ovum or an egg. All the other cells of this insect are called diploid with two chromosomes.

Mitosis is the production of cells with pairs of chromosomes by duplication of chromosomes and the formation of new cells with pairs of chromosomes. Meiosis is the production of sex cells by the duplication and division of the duplicated cells forming cells with single chromosomes. Those are used in the fertilization with cells with pairs of new and different chromosomes for this changing world.

Insect Life Cycles

The life cycle of an insect that includes physical body development in different stages is called metamorphosis. The difference between the two divisions of insects is referred to as those insects that have a complete life cycle with a pupa stage of growth and those insects that have an incomplete life cycle that does not contain a pupa stage of growth.

An insect with a complete metamorphosis goes through four life cycle stages: "egg - larva - pupa and adult ". It starts out as an egg, then develops into a larva, then a pupa and finally develops into an adult. (Some authors refer to the larva stage as the nymph stage or the larva stage.). During the larva life stage of insects that go through complete life cycles, the insect does not look like the adults. Wings develop inside their bodies under their exoskeleton and these wings do not appear until after the pupa life cycle in the third phase of the insect's life cycles.

The insects that have an incomplete metamorphosis go through three life stages of development:
"egg, nymph and adult. The adult insect that develops through incomplete metamorphosis is similar in appearance to the young nymphs except that it is usually larger and it can mate under the right circumstances. These insects do not go through a pupa stage. Some of these insects that do not have a pupa stage do not grow wings. When these incomplete life stage insects have wings, their wings develop on the outside of their exoskeleton. In most cases the adult insects going through an incomplete metamorphosis have wings or the capability to grow wings if conditions require wings. Their nymphs usually have wing pads on the outside of their exoskeletons that are visible but can 't be used for flying. Aphids are an example of the insects that have an incomplete metamorphosis.

There are some incomplete cycle insects that spend all their nymph stage in water. These nymphs do not look quite like their adult forms that are land insects. They are still classified as **hemimetabolous** insects because they do not have a pupa stage and their wings are outside of their exoskeleton. The Damsel and Dragon flies, Mayflies and Stoneflies are in this group of insects. The mosquito that is **Holo**metabolous with a complete life cycle has a larval stage of growth that occurs in water and has a pupa stage.

The holometabolous insects change in several ways during their life cycles. These stages include: egg, larva, pupa and adult. There are over eight hundred and fifty thousand species in the holometabolous that form their wings inside their bodies as they go through their pupa stage. They may only go through four or five molting stages.

The insect goes through different changes in its body. This depends on the species of the insect. These changes are called metamorphosis. There are three types of insect metamorphosis: ametabolous, hemimetabolic and holometabola.

The ametabolous insects only change in size once after they hatch from the egg. The young and adult look the same except for their size and sexual activity that the final or adult stage can carry out. The hemimetabolous insects have what are called gradual body changes. As they go through the different molts they have changes that occur in their wings and genetalia or sex organs. The hemimetabolous have three life stages: egg, nymph and adult. Because the hemimetabolous do not go through a pupa stage they develop wings on the outside of their bodies. The insects that have been here on this earth the longest and are still active are the insects like silver fish, springtails and firebrats. They grow through very few body changes as they grow in size from one stage of molting to the next stage. Their size increases as their body grows, but they have the same appearance once they are born as they have when they are adults, when they mate and when they produce their young. They feed, grow, and build a new exoskeleton, split out of the old exoskeleton, abandoning the old exoskeleton until they are adults producing eggs. The only visible sign is their change in size. They may go through fifteen molts during their lifetime.

Insect Egg Stage

The insect eggs are laid in many different shapes. The eggs can be shaped like a barrel, disk shaped, box shaped and several other shapes. Insect eggs can come in different colors with different surfaces like spines and ridges. The egg shell called the chorion is made up of two layers of fatty proteins, an outer layer (exochorion) and the inner layer (the endochorion). Some insects lay eggs with a wax layer over the outer layer. The insect eggs have one or more openings called aeropyles in their outer layer. These aeropyle holes are used as a passageway for the air containing oxygen and carbon dioxide. These are breathing tubes. Sperm from the male enters the egg through another small micropyle opening to fertilize the egg.

Inside of the egg cell is the membrane. This is called the viteline membrane. It is a delicate membrane that lines the entire inner part of the egg. The cytoplasm of the insect egg is a thin band that is distributed just inside the viteline membrane and has strands that run through the egg yolk and it takes up most of the egg. The ball shaped nucleus of the egg is in the egg yolk located near one end of the egg. The other end of the egg will have a slightly darker area than the area that contains the nucleus of the egg.

The egg is another cell of the female insect with a nucleus, but this cell's nucleus is haploid with single chromosomes. The other cells in the body are diploid with connected pairs of chromosomes. As outlined in the two hour course on "Weed Seed Control" the plant ovary contains a cell that is a haploid gamete with single chromosomes. This insect egg is also a gamete (the female gamete). A male insect will seek out the female providing her with his sperm cells that are also haploid with single chromosomes. The sperm cells are also gametes (male gametes).The female insect received the the sperm cell when she mated with the male insect. She can store the sperm in a part of her body called the spermatheca. When one of the female' eggs move by the female spermatheca a few male sperms may be released on the egg

near the microple (an opening of the egg). Whichever sperm gets to the egg first ends up connecting with the female egg and fertilizes the egg. This joining together produces a one-celled embryo that is diploid with connected pairs of chromosomes. This one cell grows into many different cells building an insect's embryo that becomes the insect's body. All of the eggs produced by this individual insect are geneticlly different from other insects. Even though the eggs appear to be alike, genetically, each egg is different. Once the egg is fertilized by the male sperm the joining of the sperm cell and the female egg cell forms a diploid one-celled embryo with genes from both the male and female chromosomes. The insect starts to grow forming all the body parts and in the last several years we have been able to learn how this growth takes place. Knowledge seeking studies like genetic engineering that gave us plants that can kill their attacking insects. Cotton has been engineered with Bacillus Thurengensis that can poison and control attacking pink bollworms without pesticide applications. These methods of insect control have given us knowledge about insect growth and existence. We still have several things to learn about insects but we do know how the insects multiply as embryos and become both useful predacious insects and insect pests that need to be controlled.

The entire insect egg doesn't divide as it multiplies like some of the other animal eggs do. The insect divides and duplicates only its nucleus not the cell. In the normal mitosis process the pairs of chromosomes in the cell's nucleus duplicate themselves and then splits with the entire cell forming two identical cells. This division of the nucleus is called cloning where all the new nuclei are the same. This division process can produce large numbers of new nuclei that can number five thousand new nuclei when they divide as many as twelve to thirteen times. These nuclei that are produced are called energids. As they form they travel through the egg yolk to the inside perimeter of the egg. These energids then produce their own cell membranes and make up a layer that is one cell thick around the yolk. They start feeding on the yolk and begin growing.

Not all the parts of the nuclei go to the edge of the yolk. The first ones drift below the nucleus after splitting off and end up in the yolk. They are the first to leave the main nucleus and start dividing, but they will stop dividing and drift about the lower part of the yolk. Then they form cells with membranes that are named; *germ cells*. Later on when the embryo forms male gonads called testes or female gonads called ovaries, these cells will be activated. When the insects finish going through their life cycles and reach the adult stage these cells will begin dividing by the process called meiosis (page 21) and they will become haploid cells that become sex gametes which are female eggs or ova and male sperm. By not growing or dividing while they are in the embryonic stage of growth the vital DNA in their cells is protected from genetic defects that may occur.

Insects and some of the other animals can carry out asexual reproduction. The egg is produced and it can develop into an embryo without being fertilized. Some plants, and one celled organisms, like bacteria, reproduce in this manner. The use of fertilization for reproduction is the usual method of producing young. The main benefit is the mixing and transferring of genes. As the world changes the new and differing emerging creatures have a better chance of survival. The insects and other animals with more than one cell in their body tend to use sexual reproduction. There are insects and other animals that use the asexual form of reproduction. Bees, ants, aphids, some snakes and even sharks have been found to use asexual reproduction. More information on asexual egg production will be discussed in the section on these insects that produce asexually.

Embryo Formation

The cells will begin to develop first on one side of the egg. These cells will form the ventral plate where the body of the insect embryo will develop. The future insect's nuclei start controlling the development of the embryo's body. Control genes called homeotic selector genes take charge of the development of the new insect body. These genes send out messages to the cell building apparatus of the cell to build body parts by activating cell growth and duplication.

A basic body plan is mapped out to be built with an axis, individual segments, special structures and finally body parts like wings and legs. The cells are built to provide digestive systems like intestines, muscles, glands, heart, blood, fat and reproductive organs called gonads. These will be added when the adult body is formed during the last life stage or adult stage. Other cells are produced to form the skin or epidermis, the brain and nervous system along with the respiratory system. The embryo body starts out in a wormlike shape but then develops into body parts with a solid structure that will cover and support the insect. This body cover is called the exoskeleton.

Exoskeleton

Insects have their bodies supported by a structure on the outside of their body called an exoskeleton. Other animals have a skeleton of bones inside their bodies that gives their bodies support. Without this exoskeleton the insect would die. At the same time these insects continue to eat and grow larger especially during their larva stage of life. Insects must shed the container (exoskeleton) that they have in order to grow but they need support before they can shed the old exoskeleton. The insect must grow another exoskeleton before shedding the old one.

The exoskeleton is on the outside of the insect's epidermis or skin. As molting begins a hormone of the molting insect is produced by the insect that starts the molting process. The epidermis and the exoskeleton are separated producing an area of space between the exoskeleton and the epidermis. This area is then filled with a molting fluid prduced by hormone activity. During this period of time the epidermal layer of cells of the insect secretes some proteins that form a new cuticle between the epidermal layer and the exoskeleton. This cultical is now a protective barrier between the molten liquid and the insect. The enzymes in the molten liquid digest the inner layer of the exoskeleton. (Two materials, chitin and protein are recycled by the epidermal cells.) Then the produced material is secreted under the cuticle. This secreted product becomes the main product of the new exoskeleron of this insect. The development of the insect embryo ends when the food that is supplied by the egg yolk is all consumed and this amount of time depends on the temperature. Once the embryo has developed it may chew itself out of the egg when the food provided by the egg yolk is gone or the size that the embryo has grown may be large enough to crack the egg shell. The shell or chorion has a weak line in it allowing the embryo to hatch from the egg and become a nymph or a larva.

When the new exoskeleton is formed the insect can start shedding the old exoskeleton. This expanding and shedding of the old exoskeleton is done by taking in huge amounts of air by gasping along with muscle contractions. The old exoskeleton splits along the dorsal part of the insect (the back or upper part) once the insect squeezes out of the old exoskeleton it continues to expand the new pliable exoskeleton to make room for more growth. The new

exolskeleton is soft and light colored. After a couple of hours the new exoskeleton will harden and darken in color.

When insects have damaged tissue or missing limbs the new exoskeleton protects and allows the missing legs or tissue to grow back. Because insects may go through several growth stages called molting the entire limb that was injured may take more than one stage of molting to get the entire limb back to a normal size like the rest of the insect's limbs.

The development of the insect embryo ends when the food that is supplied by the egg yolk is all consumed and this amount of time depends on the temperature. Once the embryo has developed it may chew itself out of the egg when the food provided by the egg yolk is gone or the size that the embryo has grown may be large enough to crack the egg shell. The shell or chorion has a weak line in it allowing the embryo to hatch from the egg and become a nymph or a larva.

Nymphs and Larva Life Stage

This second life stage of the insect is called the larva stage or the nymphal stage. Insects have different second life stages depending on the species of the insect. Other animals have this same growth pattern or something similar. Snakes shed their skin and grow a new skin. Spiders go through molt stages. *In agriculture the molting stage is one of the most costly to Ag crops.* The growth of insects during this period is one of the main feeding stages causing insect damage to growing crops. The period between molts is when the most amount of insect feeding takes place. Some insect molt fifteen times. The new space between the larva or nymph body and the new larger exoskeleton is filled with food collected by the larva or nymph and turned into expanded or growing parts of the insect. Some insect pests like the loopers and army worm consume the vegetative parts of the growing crops while aphids pierce, suck and consume the liquid parts of the growing agricultural crops.

The insect predators that prey on crop insect pests go through the same growth stages. Lady bugs have chewing mouth parts that they cut their prey with then they take in the juices and flesh at the wound of the attacked pest. They end up devouring a large number of pests during their molting and adult stages of growth. Lady bugs will feed on plant materials as adults in some situations. Another of these insect predators is the Lacewing. Lace wing eggs are placed by the mother atop tiny sticks to keep the newly hatched young from devouring the eggs of the other young that were laid by their mother. Lacewing goes through the same egg, molting, pupa and adult stages of the life cycle.

Predator insects like the lady bugs will also feed on farmers crops. Some of the lady bugs switch to vegetations instead of insect pests. The Mexican bean beetle, which is in a subfamily of lady beetles, is a leaf eating beetle and where they are a pest problem control treatments have to be applied. In the San Joaquin Valley of California the lady beetles after feeding on nectar in the mountain areas and sleeping through the cold months will require water when they become active. If water isn't available they will feed on other insects thus ing esting protein that will change their diet to insects. These are adults and the protein causes the beetles to mate. Then their young will hatch as larvae with a need to feed on other insects.

The aphid does <u>not</u> go through four life stages of growth (egg, larva, pupa and adult). Aphids go through a growth stage where it sheds its exoskeleton and forms a new one. This stage is called a nymph stage instead of a larva stage. These insects, which have a nymph stage, can still shed their exoskeletons and grow new ones. These insects are called

hemimetabolic (with three life stages) and can have as many as fifteen molts compared to the three or four that the holometabolous insects that goes through the four life stages.

Pupa Life Stage

Insects like the mosquitoes spend their larva life stage submerged in water. In the fourth instar of the larva stage the mosquito larva becomes a pupa and floats to the water's surface. The mosquito pupa has a tube that it puts out of the water to gain oxygen to stay alive. This uptake of air keeps the pupa afloat. If something disturbs the pupa it will dive from the surface of the water in a tumbling manner to escape whatever disturbed it. Then it floats back to the surface. Being in the pupa stage it doesn't need food because it ate and stored enough to get through the pupa stage. While it was swimming around in its larval stage it didn't need air. Its pupa case is made in the last larva instar stage. Just like other insects the mosquito larva uses the same body fluid that it dissolved its food with, it now uses the same body fluid to dissolve its own larva body. During its pupa stage it uses the dissolved larva body parts to make adult mosquito body parts. It makes wings, legs, and all the body parts required by an adult mosquito. Once the new body is formed the adult mosquito stands on the water, stretches out its body and flies off. The surface of the water has to be very calm for this activity to take place otherwise the standing on water couldn't take place.

Caterpillar insects make a very hard layer under their last larva skin. This layer is called a chrysalis. This is a work of art and is very colorful. It is cemented to an upright object. The hooks on the back of the chrysalis made by the insect can attach to and hold the chrysalis vessel on the upright object: usually a leaf. The insect produces a liquid that can soften the chrysalis when the adult is formed and can break out of the chrysalis.

Other insects like the moth, forms a cocoon that is formed from a string like material that is wound around the last exoskeleton of the larva. This cocoon can be enforced with dry hard hair from the last larva covering. The hair is needle like and can ward off predators. Twigs, dirt, mud and even fecal material can also be used on the cocoon. Even some leaves or pieces of vegetation can also be used for the same purpose. The cocoon has an area of weakness that the adult can split by expanding itself when the time comes to abandon the cocoon. The most famous and expensive cocoons are those of the silk moth that produce a silk cocoon that is sold commercially for some very high prices. Silk worms have been domesticated and are not a wild insect. Some insects like the flies just use their last exoskeleton as their pupa container. They don't produce a pupa covering by using the last exoskeleton, but the adult fly produces another first exoskeleton for the next life stage which is the final adult stage under the old one. Instead of dissolving the last exoskeleton they split out of it as adults.

Insect Adults

The larva is equipped for eating and growing; therefore their bodies are formed for growth. As I mentioned in the embryo section of the insect's life there are certain cells of the body that are not allowed to grow until the insect enters the adult insect life cycle. The Latin word "larva" means mask for that phase of an insect before its final body is revealed. The cells are called *imaginal or discs* and they can go through mitosis and grow by duplicating themselves. These cells are sexual cells (sperm and egg) which the larvae do not use. These cells are protected from the dissolving fluids used by the pupa to replace the larvae cells. As these stored cells start to multiply they produce haploid (single chromosome) sexual cells needed in the adult stage for mating. There are also other imaginal cells carried and stored on the nymph and larva bodies that now duplicate and divide (mitosis) for the adult life stage including the wing and leg cells along with other adult body parts. Reproduction body parts along with dispersal and migration needs, like wings, dominate the body of the new adult insect.

Although most of the feeding body parts dominate the insect larval there are species of adult insects that can cause high amounts of crop damage just like their larvae. Beetle insects are an example with their adult chewing and piercing mouth parts. Female mosquito adult insects need the

piercing mouth parts to get blood in order to lay her eggs. This is how diseases are spread causing large disease infections and massive mosquito control measures.

Insect adults have antennae or feelers on their heads and their muscular thorax or chest for supporting their wings. They have six legs and an abdomen. An adult insect uses its wings to rise up to levels in the air where prevailing winds carry them for long distances. Some adult insects like the mayfly last as adults for one day while the adult honey bee queens live 4 to 5 years. The adult mound building termite queens can last as adults for more than 50 years.

The queen of the insects has one very important role and it is reproduction. Some queens produce pheromones that keep the rest of the females in their group from having reproduction. The male adults usually have a very short life span after having reproductive sex with the females. The citrus scale male in some species doesn't have a mouth because he dies after having sex and doesn't need to eat before his short life is completed.

There are four orders that dominate the insect world. These four are: the Coleoptera, the Hymenoptera, the Diptera and the Lepidoptera.

Coleopteran Beetle and Weevil Adults

One way of defining the adult beetles and weevils from the other adult insects especially the cockroaches and other bugs is their fore wings. They have the look of a large truck with an oblong tank with legs instead of wheels. Coleopterans have a distinctive set of wings that cover and protect their bodies. These wings aren't used for flying. They are called elytra and are hard sheaths that cover the entire body. When their fore wings are lifted the real wings are exposed that are used for flying. The flying wings consist of membranes that are much lighter. Some of the coleopteran do not have these flying wings and do not fly, but they do have the elytra, fore wings, and when the hind wings aren't present the fore wings are fused together. Ground beetles do not have the hind wings and do not fly, but they are coleopteran because coleo comes from the Greek word koleos meaning sheath and "ptera" meaning wings.

The coleopteran is the largest order of insects and they account for thirty percent of the animals that are present on this earth. They come in a large number of shapes and sizes but generally they have these characteristics: Their mouth parts are formed for grabbing and chewing their food or their enemies. Their jaws can move horizontally. Some of the male mouthparts are larger than the female's and are used by the male during sexual activity and as fighting tools.

They usually have two sets of wings. With the front part covering their body and the hind wings that are membranes used for flying. They have antennae that can vary a great deal depending on the beetle or weevil. The antennae are used for smelling, but they are also used to feel around their environment. The antennae of the male may be different than the antennae of the female adult coleopteran. They have compound eyes made up of many individual lenses that produce their own refractive systems that when all these lens are joined together they form an image of what they see.

The coleopteran adult insect legs along with their wings are attached to their thorax which is the middle body part. They have six legs and these legs can be used for other activities other than walking. Some coleopteran has legs used for hopping like the flea beetle that leaps. Some of them use their legs to swim with or dig with. The coleopteran insects take in oxygen thru their thin tracheal tubes and by pumping movements of their bodies. This results in the oxygen being pushed through their bodies. The liquid in their bodies is an open system without veins or tubes found in the higher animals that possess pumping, veins and arteries or the xylem and phloem system found in the higher plant systems. The adult coleopteran abdomen is formed with a series of rings and each ring has a

hole in it that the adult insect uses for breathing. In crop insect pests like the coleopteran the food is swallowed and digested in the middle gut and is broken down with enzymes before it is used by the living cells.

Although the coleopteran adults are often pests to agricultural crops like the Colorado potato beetle, timber beetles and several others, there are also some predators and one of the most famous is the "ladybug". Just like the other insect adults many coleopteran adults only feed on nectars from flowering plants and this aids in the development of some agricultural crops.

Their nervous system consists of ganglia which is a group of nerves carrying impulses from one system to another. The pheromones are produced by the adult coleopteran insects from cells that line the abdomen. These pheromones are used to attract the insect mates. The fireflies are coleopteran and they produce light as a sexual attractant. This light producing system emits carbon dioxide and light. This chemical process is caused by an enzyme catalytic oxidation process. The main activity of the adult coleopteran is mating and laying their eggs. The adult life stage of the coleopteran can last for hours, days, months or in some cases for years.

Adult Moths and Butterflies Named Lepidoptera

Moths and butterflies carry pollen from flowering plants and are responsible for the fertility of many of these plants. Usually when you can see flowering plants there are probably Lepidoptera insects around. Plant fertilization is a huge plus for the existence of adult Lepidoptera pollinators. But the **fact** that these same adult insects can lay two hundred to six hundred eggs and some of their species can even lay thirty thousand eggs in one single day and that these eggs can hatch producing larvae that can consume and destroy vast amounts of agricultural crops and timber results in your job that produces control methods and reasons for applicators and PCA's. You are very vital for crop production and all the other activities that protect and care for our environment and our lives.

The body of the Lepidoptera adult consists of three parts: the head, the thorax and the abdomen. The **head** contains the mouth parts that most of the adult Lepidoptera use to feed on liquids from flowering plant nectars. The larvae or caterpillars have mandibles or chewing mouth parts. There are some rare moths that are descended from some of the ancient Lepidoptera that still chew their food. Today most of the adult Lepidoptera have a proboscis or snout that is segmented with small muscles that are used to curl it under the head when it is not being used for feeding. The Lepidoptera adult gains the suction for feeding by using contraction and expansion of a sac in their head that has muscles that control it. Some adult Lepidoptera feed on flower nectars and others feed on rotting fruit juices or fermenting tree sap with a proboscis that have tiny holes in the sides and a closed end to strain out the solid parts. Some Lepidoptera adults have a proboscis that allows them to consume pollen. In their efforts to feed the butterfly and moths will also pick up pollen and therefore are responsible for the spreading of pollen among the flowering plants. This allows the flowering plants to multiply along with the nectar feeding moths and butterflies. Flowering plants are now the dominant plant due to nectar feeding insects that are still multiplying on this earth. The head of the Lepidoptera insect has antennae that vary in shape between species and even between sexes. Some antennae are club shaped, others are hooked and some are tapered. Antennae are used to sense air motion, heat, sound or vibration, smell and taste. They use antennae to locate water, vapor and odors. Pheromones are one of their main odors used for the location of mates. Pest controllers use pheromones in several ways especially in their trapping programs to keep them aware of insect invasions and populations.

The adult Lepidoptera butterfly has two compound eyes. Compound eyes consist of many individual nerve ending that receive light. These receptors can be in the thousands and are located on

a raised disc or orb. The incoming light forms an image of the object that the insect sees. These small eye units point in different directions. This gives the insect a very large angle of sight. This also allows the insect to see very fast movements in a large area. It's like having many individual eyes pointed in different directions. Our human eyes are individual but have a much larger single surface to see objects. The Midsection (called The Thorax)

The thorax is divided into three sections: the prothorax, the mesothorax and the metathorax. Each section has its own set of legs. "Insects have six legs". The butterflies and moths have scales on their legs and on most of their exposed bodies. On the feet of their legs they have organs that are olfactory (meaning that they can be used to smell things that they can eat).

On the mid-section, the mesothorax and the third section, the meta-thorax is where the wings are located. These wings are also covered with scales. These scales are very colorful and are placed like shingles on a roof. Some of the Lepidoptera have wings of the same size on their second and third section of their thorax, but several have their most powerful set of wings on the third section with larger more powerful muscles to push the insect through the air. One of the largest families of Lepidoptera is the Noctuidae which is a moth and flies in the dark, uses its largest wings as hearing devises.

The third body part is the abdomen that is divided in ten segments held together with membranes. The membranes allow the abdomen to be flexible. The segments in the seventh to tenth are where the adult butterflies and moths have their sex organs. The sex organs of Lepidoptera adults are used as one of the main method of identifying them. Males have a valva or set of clasps to hold the female during fertilization. In the female basal moths have only one sex organ. These females use the same sex organ to lay eggs from and to carry out the sexual activity as it transports the male's sperm. The other moths, ninety eight percent of them, have separate organs to do both activities, one to lay eggs with and the other to transfer the male's sperm to the eggs.

When I discussed the formation of the embryo of these insects I described the storage of the sex cells. These cells make up the sex glands that are used when the female adults mature. These cells along with wing cells and other adult cells are carried through the larva and nymph stages and they are called imaginal cells and they can multiply by duplication and mitosis.

Pheromones are used by the adult female moths and butterflies to attract the males. Some Lepidoptera use sounds especially if they are not sending their mating calls a great distance. Another mating attention getter is the use of vibrations for those insects that like to dance. Some insect Lepidoptera mate only once, others mate on a seasonal basis and others do it more often when they can. Hormones drive the sex activities and any delays are called diapause. Some insects die after mating or laying their eggs. Others may mate again. The sperm that the male placed in the female may be activated after a period of time and used for a new birth and some sperm can be used long after the sperm is placed in the female.

One of the characteristics of the adult butterflies and moths besides their scales is their **wings.** Once the wings are outside of the pupa case the adult's new cuticle, or exoskeleton, hardens enough that when grabbed by a person very little damage occurs to the wings. The ability to fly is vital to the life of the Lepidoptera. Using their wings to move to food, escape other animals, find mates, seek out food and locations in which they can feed, mate and stay alive. The wings need warm weather in the range of seventy seven to seventy nine degrees Fahrenheit. They can use their wings to gain warmth from the sun, but in hot climates like my Yuma, Az. area these insects can overheat. The Lepidoptera in these hot climates have hairy scales and air sacs in their bodies and body structures that widen the distance between the abdomen and the thorax thus keeping the abdomen cooled off in hot weather. Their wings can also help the butterflies and moths to fly at fairly fast airspeeds. The darts, Southern

Dart, can fly at speeds up to thirty miles an hour. Some of these insects need and do hover with their wings when they suck nectars from flowers.

Most of the Lepidoptera adults do not have a long life. They take a short period to find a mate and lay their eggs then pass away. As I mentioned in the opening of this three hour course the life history of an insect that we are attempting to control is needed to decide when the insect pest is most vulnerable to our control method. There are stages in the insect life cycle when the insect is more vulnerable to our method of control than other stages. Some pest control methods will not control eggs and pupa. Knowing how long an insect is in its growth stage "egg, larval, pupa or adult" will determine the type of control method that will give the best results. Pesticides usually have a toxic level period of time when they are active. Timing the application to the life cycle gives better control. This is also true when pesticides are timed with harvest and plant back requirements.

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The Life Cycle of Diptera, True Flies, Mosquitoes, Gnats and Midges

The first two letters (D) & (i) in the name 'Diptera' which means *two* is because of the fact that Diptera insects have two wings. There are exceptions: some Diptera have no wings. There are a number of insects with the name "flies" like "butterflies" that are not Diptera insects. Butterflies have more than two wings. The order called Diptera is in the class of the other three orders (Lepidoptera, Coleoptera and the Hymenoptera) that contain a very large numbers of insects. Diptera includes: gnats, midges and the very famous or infamous: Mosquitoes.

One characteristic of the Diptera or flies is their enormous populations. Flies produce their young using an amazing rate of speed in their reproductive process of mating. They mate while flying in the air with the male on top. The male starts mating while flying in the same position as its female partner. They are both aimed in the same forward position. But after he inserts his genitalia into the female's sex organ the male turns around facing in the opposite direction. The male has to lay on his back to stay joined to the female or he may be able to sit upright if the torsion or his ability to allow his genitalia to twist enough so that he can remain upright sitting with his back to the wind. This mating is carried out while the insect pair is flying.

Because of this mating technique the process of mating is sped up allowing a quicker transfer of the male sperm to the female's sperm container. This very fast sex act increases the number of sex acts and a population increase during their mating season. The female lays her eggs on or very close to the food needed by the hatching young. The newborn flies hatch from laid eggs or in many cases the female gives live births of her young and the young flies begin feeding immediately because they don't have to wait to hatch from an egg.

The body parts of the flies include the head, thorax and the abdomen. Flies aren't built for walking, but they are excellent flyers. They have two compound eyes that are large with one eye on each side of their head. They also have three simple eyes like humans and these are located on the top

of their head between their two huge compound eyes. Because flies are excellent flyers they need and use these eyes both the compound and the simple eyes to aid them in flight. They alert the fly when it goes off course or yaws. These physically arranged eyes also alert the fly when their body rolls during flight and they tell the fly when and where they are either going to the right or the left. The fly uses his information from their eyes to stay stable and in control of their flight. The fly is constantly able to automatically adjust its position. The fly uses both the simple eyes each with one lens and the compound eyes with thousands of lens to adjust its flight patterns. The nerves are the carriers of this information to the fly's brain where signals are sent to adjust muscles to correct the fly's direction of its flight. Flies only have one pair of wings but they are some of the best flyers in the insect group.

They are fast. They can fly backwards and upside down. They do this to land on ceilings. They can fly in one place by hovering. Some of the midges have had their wing beat counted and they posted one thousand wing beats per second. In mating the female mosquito attracts male mosquitoes with their wing-beat. Diptera insects have only one set of wings, but they do have a set of reduced wing structures that are called halteres. These are believed to have evolved from wings and are used to stabilize while flying. The fly's head contains the antennae that are smaller than other insects to receive sounds and smells. These antennae are small therefore they do not hamper the fly's flying ability.

Diptera adults consume liquids and very finely ground food. They lap up the liquid. Some Diptera adult insects have mouth parts that are knife like and they use these to slash or cut skin and then lap up the fluid. Female Mosquitoes can pierce or inject their needle like mouth parts to get to the blood streams of their victims. Only the females of some of the diptera feed on the blood of their victims. They use the protein present in the blood for producing their eggs. These diptera female inject an anticoagulant which is in their saliva when they penetrate their host. The anticoagulant thins the blood making it easier to take in.

The saliva also contains diseases from other animals that the fly has invaded. Tularemia is one of the bacterium diseases transferred in this manner. Tularemia is named from the county of Tulare in California where I happen to have been born. Exposure with squirrels is how the disease is transferred to trappers. Other diseases transferred by these insects include a disease causing sleeping sickness. Horse flies transfer the disease to humans especially in Africa. Other diseases known to be transferred include encephalitis and yellow fever.

The populations of diptera are located in most of the earth's locations: the tropics at sea level, high in mountain ranges and the sub arctic areas. They are found in oceans far from land when they are migrating.

The Life Cycle of the Hymenopteron: Bees, Ants and and Wasps

Hymenopterans are often described as the social insect groups. The insects that we call social like bees, ants and wasps are the ones we think of as the only hymenopterans, but there are a very large number of hymenopterans that exist as solitary insects or loners. A good example is the chalcid wasp. It is a very large group of insects with twenty two thousand known species and a total estimated unknown number to be six to five hundred thousand species. People working on this number predict that a vast majority of them will be discovered and described in the near future.

These insects are parasitoids (they attack the eggs and larvae of other insects). They have more than twelve host insects in which they can be found. The Lepidoptera (Butterflies and moths), Coleoptera (beetils), Diptera (true flies), Hemiptera (true bugs) and Hymenopterans are hosts into which the Chalcid insert and lays their eggs.

The insect with the name, Hymenoptera is known for the nature of their wings which are formed from membrane. The word describing the wing comes from the Greek words *hymen* for membrane and *ptera* that means wing: *membrane wing.* They have two sets of wings with the back connected to the front with hooks. These wings have very few veins which is another trait of this insect.

Hymenopter females have an ovipositor in the rear of their body through which she can insert her eggs into protected areas like tree bark. This also allows them to place their eggs in other insects. Often these other insects are crop pests and the hymenoptera then becomes an aid in pest control. These ovipositors are also used to insert chemicals that sting other animals like us. Eggs that have been laid will hatch to become larva that will pupate and then become adults. Hymenoptera have a complete life cycle with four stages (egg, larva, pupa and adult).

Reproduction of the Hymenoptera

In the bee colonies the queen bee has an ovary that contains hundreds of ovarieles and each of them has around sixty eggs with nutrition cells. The female when mating with several males stores the sperm from them in a container in her body called a spermatheca. The living sperm lasts for several years in the long living female. The spermatheca is connected to the oviduct which is a tube that carries the eggs to the outside of the female.

When the egg is laid it is treated with the male sperm. The female can and does control the amount of sperm released to each egg with a separate muscle located around the duct or tube. When no sperm is released the egg will be unfertilized and will produce a male embryo. The male is haploid. Haploids have only single chromosomes. Diploids have attached pairs of chromosomes in their cell nucleus. The female queen bee can and does produce females that have diploid or pairs of chromosomes.

The queen decides the sex by using her muscular ring to open or close the tube carrying the sperm. Females are born being able to recognize the difference between the colors: yellow, blue, blue green and ultra violet light. Males can make out the ultraviolet which they use to guide them during their mating flight. Males do not feed because they do not have a mouth and they get along fine not seeking out the yellow pollen for a meal as do the female worker bees.

One of the kinds of reproduction used by the Hymenoptera is named parthenogenesis. The insect can produce their young without having sexual activity. No sperm is involved. There are other insects that have this type of reproduction process and some other animals including vertebrates with internal skeletons. A large number of hymenoptera produce their young in this way. This method of reproduction sometimes occurs in cycles. The chalcids wasps have their first generation of male and females and the second generation is only females. These second generation females then have male and female from unfertilized eggs by the parthenogenesis method (no sex activity). Usually parthenogenesis is caused by a change in their nutrition. The source of hormones may come from a meal which is usually larva of other insects like a beetle. Another trigger that is responsible for parthenogenesis is the number of chromosomes in the cell structure of the egg with its hereditary information or it's DNA.

The technical word "polyembryony" is used to describe the development of several individual embryos from one single egg. This can occur in the hymenoptera parasitic insects (like the chalcid a solitary not a social insect). The embryo divides into several embryos exactly alike and these become individual insects. As many as a thousand insects are produced from one egg. This is also controlled by genetic or chemical factors. This can happen along with single embryos being born with the same offspring.

Physical Differences of Hymenoptera

Sawflies: After hatching, during the sawflie's larva lifecycle, it has a prominent head with chewing mouthparts, eyes and prominent short legs under their abdomen (like a caterpillar). The larvae of the bees and wasps are grub-like with a head and chewing mouth parts, but they do not have eyes or legs. Larvae of the parasitic wasps have a reduced body form. These wasps do not have a prominent head, no eyes or any other appendages. The adults have chewing mouth parts except for the bees that have a proboscis (which is like a trunk on an elephant only much, much smaller). They use it to suck up nectar or honey. They have compound eyes with many lenses. They have a triangular mark on their front set of wings. They have two sets of wings with small ones in back and large wings in front. These wings are linked together with hooks thus helping the wings to move together when in use. The adults have a narrow waist (a wasp waist) between the thorax and the abdomen. The sawflies and horntails have thick waists and unlike the other Hymenoptera they feed on vegetation instead of other insects.

Chalcid Wasp and Other Secular Insects

Chalcids have a life cycle that includes all four stages; egg, larva, pupa and adult. These wasps are the largest group within the Hymenoptera order of insects. Of the known species there are twenty two thousand known chalcid wasps and between sixty to five hundred thousand species. So there are a large number that haven't been named at this time. The good news is that these large numbers of insects are parasitoids that attack agricultural pests when these pests are in their egg and larval life cycles. The pests include Lepidoptera which includes: butterflies and moths, Diptera or flies, Coleoptera or beetles, Hymenoptera or true bugs and they attack other Hymenoptera which is their own order of insects. They also attack nematodes and spiders. Some of the species feed on vegetation including seeds, stems and they form galls on the stems and trunks of some plants. They are used in pest control methods when used to parasitize specific crop insect pests. There are pest control businesses that rear these types of chalcid insects.

The solitary wasps unlike the social Hymenoptera lay their eggs, one in each nest or cell which they stock with more paralyzed insects and spiders. As the individual larvae hatch from the egg they feed on the paralyzed insects provided by the adult Chalcid wasp. Some parasitic wasps lay their eggs either in the parasitized insect or on the parasitized insect where they live out their larval life cycle and in some cases their cocoon life cycle. The Chalcid larva uses the body of the insect that they inhabit as food. There are bees that do not have a social life and they are solitary and live alone without other bees. They lay their eggs in the bee hive cells of other bees. They do not collect pollen, but feed on the pollen of the host they have invaded. They kill the eggs, take the hive cell over and eat the food that is then carried to them. These invading bees do not have the social bee's strong jaws and legs needed to build their own bee nests.

There are solitary lone bees that build individual nests that they stock with pollen and nectar. These include the sweat bees, leaf cutting bees and carpenter bees. The female makes her own nest. She doesn't have worker bees. She makes nest cells to lay her eggs in and she collects her own nectar and pollen. She makes her own wax for the nest cells. She doesn't live very long as an adult. She may build another nest and lay another egg supplying an amount of food for her young depending on the length of the season. Her young female will hatch; become a larva, then a cocoon and then another adult female. The young female will share the nest with her mother splitting the work together. This lasts for one summer. Then they both will go to a *swarm* where the younger bee may end up mating with a male bee and form her own nest and start laying eggs or she may again join with her mother raising and taking care of the nest's larvae and fighting off any insect that tries to invade the nest. The

number of mother and daughter nests may grow in size but it is still not a social arrangement where each bee has a set job.

Dependent or Social

Bees that are social have evolved from the mother and daughter type of hive that has become a social hive with a large number of female bees. The female queen bee has evolved into a female that only lays eggs. She is fed and cared for by female bees that have become worker bees with specific jobs. As they emerge from their cocoon or pupa life cycles they start working at individual jobs. The first day they clean the cells where the eggs will be laid by the queen bee. After a few days of this task the young adult bee will start feeding the young larvae with honey and pollen. By the sixth day she is able to produce a food from her glands for the young bee larvae. Then by the sixteenth day the young worker bee is able to produce a wax material that she can build cells (honey combs) for the eggs that the queen will lay. After this the young bee adult will become a worker guarding the cell and bringing in food until she dies. The worker bees gather nectar from flowering plants. They fly from flower to flower using their proboscis which is a tube like mouth part used to suck up the nectar in the flowers. As they do this the pollen of each plant is carried from flower to flower a natural process that sexually fertilizes the plants. The nectar is stored in one of the stomachs of the worker bee. In the bee's special stomach the bee has enzymes that break down the many sugars and this breakdown reduces the crystallization of the sugars. Back at the hive the worker bee regurgitates the modified nectar that is taken up by the hive bees. The hive bees have their own enzymes that further process the nectar that she regurgitates into the hive cells. The nectar still contains high amounts of water. To rid the nectar and enzymes of the excess water the hive bees beat their wings providing air to this liquid ridding it of the excess water and producing honey. This honey has only fourteen to eighteen percent water where as the nectar had eighty per cent water. The honey is stored in bee hive cells made of bees wax by the hive bees.

The queen bee feeds on a food of a material called Royal Jelly. It is produced in the glands of the worker bees. The entire larva which includes the queen bee, the male drones and the female worker bees receive this gland material called royal jelly from the glands of the worker bees for the first three days after the larvae hatch from the eggs in each cell of the bee hive. On the fourth day, after hatching, only the queen bee and a select few of the hive's larvae will receive the royal jelly. The rest of the bees in the hive eat regular honey.

When the queen is getting old or sick or the hive is too crowded for the hive bees to handle, the worker bees start feeding the royal jelly to a selected few of the worker larva. These larvae grow into larger queen bees. On that fourth day all the royal jelly produced by the glands of the worker bee adults is collected and stored in the queen bee cell and the selected larvae cells of the hive.

When people want to harvest royal jelly, queen cells are harvested. The chemical in royal jelly that appears to do the job is a single protein called "royal jelly". When this chemical is fed to fruit flies there is an increase in their size and their ovary development. This material works amazingly well on the queen bees. They are larger and they live a lot longer than the other bees. Humans apply it for their skin and have said that it does work. How! I don't know? There is some research being done on it and some reports of side effects.

Once the larvae that have been fed the royal jelly reach adulthood and the hive has more than enough bees, a swarm occurs where the new queens and drones mate. The young queen bees will mate with several drones storing the semen in their bodies and using it to fertilize some of the eggs as she lays them. When the population in the hive builds up the old queen will leave the nest to a new young queen. Then the old queen will leave the nest with several worker bees who have loaded up

with honey. Then they will all fly to a new location to build a hive where they will build new cells for the queen to lay eggs in.

Communication in Hymenoptera Insects

Insects communicate to one another by using several methods. The use of pheromones is one of their most well known; but in the hymenoptera social insects, one of the communication methods performed by the honey bees is a dance used to inform the worker bees where the best food area is located. Along with the location dance, the odor of the flowers where the good nectar is located is carried back to the hive. The other worker bees can detect this odor with their sensitive antennae. The returning bee can also give information including how much is available and how good it is using other methods of communicating.

The returning worker bee gives this information by using a dance to describe the quality and the location. The noise that the worker bee makes as she passes on this information gives the worker bee information on how good the food is. If the food is near-by a round dance is performed. If the food is more than two hundred and sixty feet away a tail wagging dance is used by the guide. The guide will use the number of dance cycles and the time needed to perform the cycle to tell how far from the hive the food is. Ten cycles in fifteen minutes means that the food is three hundred and thirty feet away from the hive, but if she takes fifteen minutes to dance one cycle the food is thirty three thousand feet away. This also gives the worker bees the amount of energy needed to get to the food.

She uses the suns position as a base to demonstrate the direction of the food source. If she also carries her tail either upward if the direction of the food is toward the sun and a downward position of her tail if the direction is away from the sun. She uses the side of the hive to do her dance cycles and lines an angle between her line of direction to the food and the line of direction to the sun, if her run is thirty degrees to the left of the sun that's the direction of the food source. She has a sensitivity of where the sun is located even if the sun is hidden by clouds or other objects such as trees that she will use when the sun is hidden. She has what is called sensitivity to the polarization differences of the sun so the other worker bees follow her directions to the food source.

When the population of bees split up to find a new hive, the bees are sent out to locate a new nest. When they come back they do the same dances to show the direction and location of the new nest.

Hymenoptera Bumblebees

Another social insect is the bumblebee. They have assigned tasks that take care of one another. They are set aside by their orange and sometimes red color of their bodies with some bodies that are black with yellow and black bodies which are soft and have long hair giving them a fuzzy look. Another distinction when compared to other bees is the presence of a concave skin area that is shiny and bare without hair on the leg used to carry pollen. Bumble bees feed on nectar that they collect and bring back to their hives.

Their organs are located in an enclosed container of blood that is circulated by the pulsing of an aorta (a large vein that carries blood from the heart) with muscles at the top of the body's back. Like the bees, the queens are fertilized by males and the sperm is contained in the spermatheca that is located in her vagina, then the queen controls whether the eggs that she lays receive sperm or not. The eggs are laid through the queen's oviduct. This is a transfer tube located between the ovaries and the outside of the body. The eggs that receive no sperm produce males while the eggs that receive

sperm produce females and queens. Hormones in the queen stimulate the growth of her ovaries. She has a full supply of hormones while the worker bumblebees receive a lesser amount of these hormones thus the workers have smaller and less active ovaries than the queens. The queen can supply enough hormones for certain larvae that allow them to become queens when they emerge from their pupa life cycle. These new queens will mate with the male and form their own nests once they decide to leave the nest.

Bumblebees are found in higher altitudes due to their ability to exist in cooler temperatures. The larger bumblebee can regulate their body temperature better than the smaller bees. Bumble bee hives are smaller because the size of the bumble bee takes up more room. Bumblebees are found in nests in tunnels in the ground and may have wax canopies built over the opening for protection and insulation from the sun.

Hymenoptera Wasps

Most of the wasps are parasitic. They live on or in other insects. Others are not parasitic. They have protruding from their backside an ovipositor. They use it to lay eggs and its shape allows the parasites to lay their eggs inside the body of other insects. The Sawflies use their ovipositor to lay their eggs in plants. It's constructed to pierce and cut into the skin of the plant. Sawflies do not sting with their ovipositor like the wasps and bees.

I lived in California's central valley I picked grapes as a kid and I can remember reaching into a grape vine for a bunch of grapes and getting a nest of yellow jackets. Wasps and bees have stingers that place venom in the stung location. They only stung my hand, but they didn't leave a stinger in my hand. After I grew up and started sweeping fields of alfalfa seed crops in the early mornings, the alfalfa plants were wet and the bottom of my net got wet. The bees that I happened to catch in my net stung the net. When I grabbed the bottom of the net I contacted the honey bee stingers. Honey bees lose their stingers and die when they sting, but yellow jackets keep their ovipositor or stinger and go on to sting again and again.

The name Yellow Jacket is used as a name for a predatory wasp here in the continent of North America. In other areas the name is "wasps". Their color is black and yellow. Some have their abdomen colored red instead of black. They fly in a rapidly side to side manner as they get ready to land. The name hornet is given to the yellow jackets that have their nests above ground. As I mentioned the female can sting several times, but they are good for agriculture because they are predacious and kill crop insect pests.

Yellow jackets are about a half inch long unless it is a queen and she is larger at three quarters of an inch long. They don't carry pollen on their legs like honey bees and they don't have a lot of hair on their bodies. Unlike the honey bees the yellow jacket will sting several times without losing its stinger. The yellow jacket has mouth parts that have mandibles that they use for chewing insects. They have a spout shaped mouth to suck up the nectar and fruit juices if there is fruit available. They are social and their society consist of workers and queens and they live in nests made of paper that is made from pieces of wood that they chew up to form a pulp. They make nests that can have a high amount of cells where worker bees tend to the young, similar to honey bees. Yellow jackets are social with specific job assignments.

A yellow jacket queen that has mated will emerge in the spring time of the year after living through the winter months. She will build a nest by collecting scraps of wood, chewing them up, building a nest and start laying eggs. She will lay the eggs in the nest's cells. When the larvae hatch from the egg she will feed them herself. As the larvae go through the pupa stage and become adults

they will take over the hive work duties as workers. They will protect the hive, hunt and carry food to the larvae and queen, expand the size of the hive and perform other duties needed by the hive.

Their food consists of masticated insects and any meat of animals that have recently died. They are great at killing and eating Lepidopteran larvae. A friend of mine lived on one of the San Juan Islands near Seattle, Washington. I visited him and one of the fields near his house had tunnels with yellow jackets. There were a lot of them, but they didn't attack us when we walked near them.

As the hive population increases more queens are produced by special feeding of the larvae so that they will become queens when they go into their adult life cycle. Male or drones are produced by female bees that have not been mated. These drones mate with the queen bees and the hive expands. As the queen's age and die, winter sets in and the queens seek places to live throughout the winter so that they can start a new hive when sprin g arrives. The nest will breakdown. Some nests will exist, but the yellow jackets will not use them. They will build a new one the next spring.

Hymenoptera Ants

Another insect in the Hymenoptera order that has a great deal of available information is the ant. This insect is a social insect that divides up the work for the good of the colony. The main difference between the ant and the other insects that are hymenoptera is the antennae of the ant. The ant antennae are bent inward like elbows and they have a very slender waist. Another difference between ants and the
other Hymenoptera is the use of teaching by ants. Scientists who have studied the ants have observed older ants teaching younger ants how to follow one of their many trails that the ants lay down from nest to food areas. The leading older ant will slow down and even stop to check out the following younger ants' use of the trail. Once the older lead ant sees that the younger ant is following properly the older ant will continue to lead the ant to and from the nest. This use of teaching hasn't been observed in other species of insects.

The queen ants and drone male ants grow wings. The queen will lose her wings shortly after finishing her mating flight. The female queen can live to an old age of thirty years. The female worker ants live from one to three years. They are active as long as the weather is mild. In the cooler regions of the earth they go into a dormant state during winter months. The larvae will go into a state of diapause. The diapause state is brought on by specific conditions and is broken by certain stimulants whereas the dormancy can be only a period of reduced activity. The male drones have a very short life span. Once they have mated they only live for a very short period of time, usually only a couple of weeks. The ant workers, soldiers and tenders of the larvae and the nest are all females.

Ants go through four life cycles: egg, larvae, pupa and adult. Being an insect they have exoskeletons. The eggs that are fertilized by the males during the queen's nuptial flight when the adult queen has wings will produce female workers or queens. The unfertilized eggs that the queen can produce will result in males or drones. Some ant queens will mate with many drones while other queens may only mate with one male. The drone goes into flight before the females. The drones put out pheromones that the female follows through the air. Some female ants mate with several males and other females will only mate with one male or drone.

The mated female will find a place to form a colony. Ants have colonies and bees have hives. The first eggs that produce larvae are weak and small compared to the later worker ants. As soon as the female starts a colony she loses her wings and becomes an egg layer that is fed by the workers. These worker ants go through the inactive growth stage of the larva then they pupate and finally end up as adult worker ants.

Ants communicate using touch, sounds and pheremones. Their antennae are used for identifying scents. They are without wings and they use the soil to lay out trails that they cover with pheromones. The trails with pheromones have to be treated with pheromones constantly to keep them fresh. The queens emit fresh pheromones constantly. When these queens slow down in their production of pheromones the colony starts raising new queen larvae by increasing food to certain larvae.

Ants have to defend their colonies and they often fight vicious wars with other ants. They use their mandibles of their mouths to fight. They also use their ovipositer at the rear of their abdomen to sting their enemies. Some ants can spray chemicals like formic acid on their enemies.

Navigation is used by ants to find food and find their way back to their colonies. They have an internal system that keeps track of the number of steps taken to measure distances that they have traveled. They also use their eyes to judge distances from stationary objects that they move around. For direction the ants use their present position from the sun. They need these position changes to gage their distance from their colony traveling the shortest distance to conserve energy.

Ants use their sense of smell to identify their selves to the colony. The colony ants attack the ants that do not have the right smell and these ants are kept out of the colony. Other insects are kept by ants. Aphids that produce honeydew that the ants feed on are one of their favorite foods. Ants tap the bodies of aphids to get the aphid to produce droplets that the ants then consume. Ants will keep predators away from the aphids in return for the honeydew that the aphids produce. When the ants move their colony to a new location they will carry the aphids with them. Some caterpillars called ant-loving caterpillars are herded by ants to feeding areas. In return the caterpillars produce honeydew that the ants consume. The caterpillars are sometimes taken into the ant nests where the caterpillars feed on the ant larvae. There are ants that feed on insects that are trapped while feeding on plants that are fed on by fungus that produce a sticky material that traps the insect that the ant feeds on. Whew!!!!

Ants are damaging pests in some situations. Carpenter ants infest wooden buildings causing structural damage. In crops where ants have a relationship with aphids the use of ant pesticides are used to control ant colonies thus controlling aphids. Tree crops are one of the crops checked and treated with the use of soil applied spot treatments using ant baits.

Hemipteron or True Bugs

This order of insects has only three life stages (egg, larva or nymph and adult). The previous four orders were put in according to the size or number of insects in the orders. The other four preceding orders have more species than these Hemipterans. The four that are larger include: Lepidoptera,
Coleoptera, Diptera and Hymenoptera. All four have a pupa stage of growth and this may be why they are more numerous when it comes to the number living species. Hemipterans are the largest order of insects that only have three life cycles called Hemimetabolous insects. The others with four life cycles are called Holometabolous insects. (I've got to get away from these big words or I'll never get my ten thousand words per hour.)

Most of these insects, hemiptera, are plant sap suckers. There are some of these insects that are parasites on blood producing animals and other insects. The predator called the Damsel bug is an example of "a good bug". Damsels live off of lygus, cabbage bugs and aphids. So these true bugs or hemiptera aren't all agricultural pests feeding on our crops. Some of these hemiptera are water based insects that have life stages in the water. Some of them walk on water instead of swimming using the

surface tension of water to stay above the water. The swimming species have paddle like legs to help them move through the water.

The name Hemiptera is taken from the Greek words Hemi (half) and pteron (wing). The base of the Hemiptera front wing is hardened and the ends are membranous. The wings can be tent-like and they can overlap. The beetles are different and have their entire fore wing that is hardened and in most cases the wings don't overlap. Some Hemiptera do not have hind wings, but the ones that do have complete membranous hind wings. Their antennae have five segments and their mouthparts that form a prow or pointed beak is used to pierce plant tissues and then it is used to suck in the sap that is available. The Hemiptera that are parasitic use their mouthparts to attack other insects making them a pest controlling insect that is benificial to agriculture. There are other insects that have similar mouthparts like the thrips that are a pest to agriculture.

The life cycle of the hemipterans is very different than the other orders that I've written about. Hemipterans do not have a pupa stage between their young and their adult stage of growth. They go from an egg stage to a nymph stages then to their adult stage. Instead of a larva stage the hemipterans have nymph stages. The nymph stages look like the adults, but the adults do grow wings in most cases and have fully developed sex organs to produce fertilized eggs with pairs of chromosomes.

Hemiptera (Aphids)

There is a great deal of information on aphids. This is because in argiculture aphids are one of the most distructive pests to cultivated crops. They are in the Hemiptera order and the super family called the Aphidoidea. Aphids have two compound eyes with several lenses. Above each eye they have two small eyes that contain only three lenses. These are located above and behind each compound eye. Aphids can change when conditions change. The female adults produce young without fertilization when conditions are good. They can also produce winged aphids that can fly to nearby fields where more food is available. Female aphids can also give birth to male aphids when conditions are poor for producing young by fertilization that produces different genes that will allow them to survive the harsher conditions.

Even the day length can have an effect on the female causing her to switch from baring live young nymphs to laying eggs that can last through the winter months in a dormant stage. These eggs then hatch in the spring when weather conditions are better and more food is available.

One of the traits of hemiptera is the piercing mouth parts; aphids use these mouth parts also. Aphids feed on the phloem and the xylem. The phloem is a vessel in growing plants under very high pressure. Once the aphid punctures the phloem tube she sits back and lets the pressure push the food into their body. Sometimes aphids have been observed feeding on the xylem. When this happens the pressure put out by the xylem is so low that the aphids have to suck harder to get any nourishment when compared to the feeding on the phloem tube in plants. The xylem produced liquid is higher in water content. The water dilutes the content of amino acids and sugars that insect's need. The concentration of sugars and amino acids is less than one percent in the xylem.

Animals, which include humans and insects, are only able to produce about half of the amino acids that they need. Plants produce all the known amino acids; therefore animals like insects get all their needed amino acids by eating plants or other animals that eat plants.

Scientists when they observed the high amount of xylem tube feeding by aphids thought that the water that they sucked out was needed to offset the periods of dehydration that usually occurred before aphids started feeding actively from the plant xylem. Further study showed that aphids used high amounts of xylem water even when there were no signs of dehydration. The high amount of plant

sap that is in phloem that the aphid has been feeding on gives the aphid a high amount of sucrose that can concentrate in the stomach causing a high amount of pressure. This pressure can build up to the point of causing the death of the insect. To avoid this build up of sucrose the molecules of sucrose are turned into a material that the aphid can pass out through the hindgut as honeydew. This honeydew is passed out of the body and the stomach problem is healed. As the honey dew is moved from the hind gut to the outside the deadly pressure is reduced. At the same time the high water from the xylem is used to reduce the stomack's osmotic pressure. This is pressure caused by two different solutions divided by a membrane pulling agaist one another. This is how the aphid's honey dew is formed.

Another thing that has to be corrected in order for an aphid to exist is that the plant sap that the aphids suck from the xylem and the flowing sap they get from the phloem do not supply enough amino acids for aphids to exist. So there is a bacterium that lives in special cells inside the aphids. These particular bacteria are not animals and they can therefore recycle a waste that the host aphids make called glutamate and the bacteria make the needed other amino acids required for the aphids to stay alive and multiply.

Ants eat the honeydew that aphids produce. As I mentioned aphids will begin laying eggs as winter weather sets in. These eggs will not hatch until the weather improves in the spring of the year. The longer dark nights and cooler temperatures cause aphid females to change their birthing operations. The female aphid can produce and lay eggs instead of giving live birth. Some ants will find the eggs on growing plants and carry these eggs to their ant colonies where they store them through the winter. In the spring time the ants will carry the aphid nymphs that hatch from the eggs back to the plants and protect them from predators. As the aphids feed the ants will rub and stroke the aphid nymphs helping them secrete honey dew. There are certain bees that also use aphids to produce the honey dew which these bees use to make honey for their hives.

Aphids can do a great deal of damage to crops. The honey dew cause the spread of fungus that damages the crop making it unfit for harvest. The heavy feeding by a group of aphids can reduce the vigor and the yield of a crop in a very short period of time. The expense in preventing the buildup of an aphid infestation takes away profits needed by growers to continue their farming businesses.

Hemiptera White Flies

Whiteflies are an insect that became a major pest in the warm parts of the California and Arizona agricultural areas. The Hemiptera trait that white flies have is that females are diploid and have two copies of each chromosome and males have one copy of each chromosome and are therefore haploid. The female hatches from fertilized eggs while the male hatches from unfertilized eggs. The membrane wings are white and when resting or when feeding the wings cover the light yellow colored body. Another trait that is Hemiptera related is the piercing sucking mouth parts used by the white fly to feed on the plant's phloem. Whiteflies also produce honey dew which is another trait of the hemiptera.

White flies have been identified since eighteen ninety six, but they became a major agricultural pest in nineteen eighty when a new strain developed and became a pest in vegetable crops in the southwest and also in Florida. Within five years this strain, named the silver leaf whitefly became one of the most serious pests in these areas. It is said to have cost the growers over one hundred million dollars worth of damage in five years. I was in the Yuma area during that period checking vegetable fields. We tried several methods for control and the University of Arizona put in a great deal of effort and success in dealing with this insect pest. This particular strain was found to be *Bemisia tabaci*. It is also called the sweet potato whitefly. In the Yuma area we found that the cool weather that comes in

November killed the adults and larvae and our vegetable crops were able to survive, but cantaloupes in the spring and summer months had some harsh problems surviving until products and control methods were found by the University of Arizona Ag Department to deal with this insect pest.

The adult female will lay from fifty to four hundred eggs on the underpart of plants. The eggs are laid in groups, sometimes in circles and sometimes scattered. The eggs are originally white and change into a brown color before hatching. Magnifying glasses are used to observe these eggs. It takes five to seven days before the hatching occurs.

The first instar is a crawling stage for the young white fly that has a greenish body that is flat shaped with legs that it walks on to find a desirable feeding site on the plants leaf. As it grows it molts or grows out of its silver skins that can be seen lying near the feeding nymphs. These nymphs are without legs and antennae. This last nymph stage is oval, white and soft. After the nymph starts feeding it will not leave the feeding spot until it goes through four molts and a last molt where it grows wings and becomes an adult with mating and birthing bodies.

The eyes of the last stage turn red. This is called the red eye stage. It is during this stage that we as field checkers get ready to spray the field. When we see a group of red eyes we know that the white flies will grow wings and then it is time to spray. The adults will have light yellow bodies and white wings. The wings are covered with a very fine white powder. The silverleaf whitefly holds its wings tilted vertically forming a rooftop effect. The wings don't come together like other whiteflies. The silver leaf whitefly is different in that other whiteflies have a great deal of white wax around while the silver leaf whitefly has very little wax and in some cases none. Silverleaf whitefly has a greater capability to reproduce, they infest a great many more crops than other whitefly, they feed on a greater amount of the crop than other whitefly and they produce a much greater amount of sticky honeydew.

The control of the white fly has brought about the use of combinations of insect predators and growth regulators. Pesticides are also used. The use of pesticides is carefully applied at certain times during the growth stages. One material called Admire is applied pre-plant to the crop soil. The predators are released in stages over the growing period to have them available throughowt the growing season. Field checking to see how the predators are working is vital. Some pesticides are compatible with the released predators.

Certain oils have been used sucsessfully. Crops that are prone to whiteflys like melon crops are disced in as soon as harvest is complete. The term "intergrated pest control" IPM is vital when dealing with this type of insect pest. Timings to allow cool temperatures to lesson the whitefly infestations plus plastic row covers are used in whitefly control. Another practice in whitefly control is to know where other crops that attract whitefly are located or will be located. If possible do not plant downwind of these crops. Grow the crop to get the shortest season that is possible.

Hemiptera Scale Insects

There are close to eight thousand described species of scale insects. They get their name from their appearance. If you've ever cleaned a fish and seen the fish scales that are the fish's skin you've seen what looks like most of the scale insects. Some of them have the appearance of oyster shells. Scale insects, at least the females, live most of their life under this scale like covers. This is one of the reasons that they are in the hemiptera order. The male has the wings which usually only includes two forewings and very small hind wings. The male only lives long enough to mate.

The first instar of the nymph stage of the female has legs and these nymphs are referred to as crawlers. They look for a place on the plant to put in their mouth parts which are piercing and sucking. They may find a feeding site on the same place on the plant they were born on or they can move

around looking for a feeding site. They may blow away and start a life and a new colony on another plant. The female adult can produce young without mating with a male. She will put out pheromones if she does use a male. Once she finds a feeding place she loses her legs and starts to grow.

I will use as an example of the Red Scale which is a serious problem in the California citrus industry. In Arizona the districts put out traps that catch Red Scale. When the traps produce Red Scale the area around is treated by the district. This has worked in keeping Red Scale from being a major pest in Arizona citrus.

During this first instar the female nymph secretes a material that covers her body forming a white cap. As the cap forms a circular ridge is made that forms a nipple on the top of the cover. The liquid that is forming the cover flows onto the plant surface and becomes a whitish gray.

The scale insects feeding tube is pulled out of the plant when an instar or molt of the scale nymph's skin occurs. The scale nymph is sealed off with the cover it has formed for its first molt or cast off skin. If you lift the covering scale you'll see that the growth of its body has a yellow cast to it. During the second instar the female scale nymph reinserts the feeding tube into the plant and begins feeding. An orange ring is formed in the nymph's cover from the remains of the first molt's cast off skin. Counting the number orange rings around the nymphs dome is a method used to determine the growth stages of the scale. A skirt is formed around the scale nymph's cover. This gray colored skirt is a secretion of wax and protein produced by the scale nymph during its second instar. The cover or dome is sealed to the nymph's body and cannot be separated.

The female scale nymph goes through another molt of its skin. Not of its cover or dome. As it sheds its skin it again pulls out its feeding tube and when the skin is shed it replaces its feeding tube and resumes feeding. An orange ring formed from the second skin that was cast is now visible.

The third instar stage has a more circular shape to it. The bottom edge of the third instar scale nymph's body protrudes from the female's body to the outside of the gray colored skirt around the body. The female allows her sex organ which is an appendage that is outside at the edge of her three formed scales. The winged males are able to locate this appendage (which is the female's sex organ) and mates with the female. After the female has mated with the male the appendage which is referred to as a pygidium withdraws under the dome to prevent mating with other males.

The female will lay eggs that are formed in her body. She can produce eggs without mating with a male. The eggs do not have to be fertilized. The eggs produced by the female hatch with legs that carry them out of the cover. These first instar nymphs are very small and start moving out of the female's body cover using the legs that they will not have during their second instar.

The male scale nymph looks about the same as the female scale nymph during the first instar. They have six legs and move about as crawlers. As the male scale nymph goes into the second instar of its life cycle, its body is different from the female scale nymph. The male gets a longer body whereas the female's body is round. The male scale nymph develops eyes. The female doesn't.

Scale males go through life stages that include larva and adult stages. The male has legs in both stages. In its adult stage it has developed genitalia to be used in sexual fertilization of females. The female's sex organ is extended outside of the scale that she lives in. She also emits pheromones to attrack the male to her scale home and her exposed genetalia.

The male has antennae that he uses to locate the female. He also has a prominent head, wings, thorax and abdomen. He mates with a female inside her scale and the male stays outside of her scale. After mating the female pulls her genetalia inside and eventually starts laying eggs that hatch into scale insects that when they reach the adult stage can give birth without fertilization producing male scales and also give birth to female scales after having mated with a male scale.

One of the major conditions that increase scale infestations is the environment that exists in a crop. The number of scale can increase because of the lack of natural enemies. Examples of this are the armored scales that include the California red scale, oyster scale and the San Jose scale. None of this scale produces the heavy honeydew that many other scale produce. The scale goes through the formation of the covering round scale during their instar growth. They stay in one location throughout their life after losing their legs in their second instar. They are protected by their covering scale from most pesticides. Predators that control these types of scale insects are the lady beetle that was introduced into this country to control scale insects.

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Except when scale predators are harmed by ants, the dust of broad spectrum pesticides can kill good and bad insects along with scale insects. Scale insects are mainly controlled by insect predators. As conditions that kill scale predators increase, the use of oil sprays is used on the crop to allow the predators to multiply. Thorough spraying at the right time of year of narrow range or horticultural oil spraying will give predators the upper hand. Oil sprays should be applied during the dormant season or soon after the scale crawlers still have legs. This is during late winter and early summer. When applying oil sprays complete coverage is required, even the underside of leaves must be sprayed. This is especially true when controlling armored scales. Armored scales are harder to control. Checking to make sure the applications are working requires that you look under the armored scale. To do this you have to flip their protective scale covers to check whether they are dead or alive.

Ants husband or tend scale insects to obtain the honey dew that scale insects like the soft scale insects produce. Ant trails can be followed to the areas where ants farm scale and other insect pests that produce honey dew when they infest growing crops. Inspections of the tree trunks and limbs that ants use to travel on to care for sucking insect pests like scales should be made during the off season. The ants will have swollen abdomens full of honey dew. There are several ant pesticides available once you find the ant colony trails. Ant baits are available and can be very effective for controlling ants.

One thing that adults of parasites need is food and most of the *adult* parasites like lace wings, lady beetles and wasps get there food from nectar and pollen. Their young larvae feed and exist on the insect pests like scales, but the adults of the larvae predators need nectar and pollen that they get from flowering plants and trees. Growing flowering plants in the crop fields will attract and multiply the natural adult parents of the predator populations. Watering the fields with water spray systems to keep the dust down is also a help to increase adult predators of scale insects. The water spraying should be done during mid season when the leaves get the highest amount of dust.

There are several pesticides that can be applied for the control of scale insects. Some of these materials can also be injected into the soil and then they are taken up into the tree crop roots. This cuts down on drift problems. The systemic insecticide called Imidacloprid has been very effective when applied in this manner. An application in late winter or early spring before irrigation has to be made to reduce the loss of the insecticide due to leaching.

Thysanoptera (thrips)

This order of insects is another very small insect that we deal with in agricultural pest control. Thrips is in the kingdom; animal; the class: insecta, and the order: thysanoptera. It gets its name (thysanoptera) from its fringed wings. The Greek word, thysanos, means fringe and this describes the wing that thrips have. The (-optera) means wing. The word thrips sounds like a definition describing their flight technique. There is also a Latin word (thrip) that means woodworm and it originated from a Greek word. So the scientific genus name is now "thrips". In this group of insects "thrips" there are around five thousand species. In agriculture thrips do a great deal of damage to the skin of the crop, but there are species of thrips that feed on other insects and even fungal spores and these are beneficial to agricultural production.

Thrips are classified in with the other insects like aphids because they do not have four life cycle stages. Their life cycle includes: an egg stage, a nymph stage and an adult stage. They do go through a life stage that is similar to a pupal stage in that they find a dark area on the plant, in buds or the bark. Some of them will even form a cocoon or even go through two cocoon stages. During this stage they grow wings and gain sexual body parts. This is not considered to be a life cycle; therefore thrips are in the same class as the aphids and white flies with three life cycles: egg, nymph and adult.

Depending on the species the females lay their eggs using an ovipositor to cut a slit in the leaf or stem of the growing plant. Some females only lay one egg per slit and the eggs are very, very tiny. Other female species that do not have ovipositors lay their eggs either one per area or in small groups of eggs. The thrips hatch as wingless nymphs and go through two molts as active nymphs before going through their quiet stage that is similar but not the same as a pupa stage, then they become adults.

Thrips are very small with the largest at a half inch in size. When thrips reach adulthood their bodies are elongated with strap like wings. Their wings have a ciliated fringe. Cilia are very small pointed flexible hairs extending from an edge that forms a fan like appearance. They have two pairs of these wings. Their body is cigar shaped. Their legs have structures where they have feet that allow them to climb up stems and leaves vertically.

They feed on the plant's outer layers of cells that are newly formed and are tender and juicy. The damage takes place on main veins or ribs of leaves. On citrus the damage that we locate increases as the new fruit enlarges. Juice production is not damaged, but the quality of the fruit is lowered. Some feeding done by thrip can results in unsightly gall formations on the fruit and the plants.

Instead of two mandibles for the mouth (a right and left mandible) thrips have a very small right mandible and an enlarged left mandible. This is used to penetrate the leaf surface allowing the thrips to inject their mandible stylet into the wound. Then, the thrips can inject enzymes that will digest and turn plant cell parts into liquids that can be drained into the thrips mouth. When checking for damaging signs of thrips this is how the scarring marks that you find are made by the thrips insects.

Thrips can carry and spread diseases to crops when they feed. The thrips adults have wings, but they aren't great flyers. They are moved by winds from field to field. Because of the small size of thrips their populations can explode when they are carried about the world by all types of transportation from country to country. They are attracted to bright colors which include: white, blue and yellow. The amount of produced offspring by thrips is one of the reasons that thrips are such a serious pest in agriculture. Females do not have to be fertilized by a male in order to produce offspring. Unfertilized eggs will produce male thrips and fertilized eggs produce females. Some thrips can produce fertilized eggs that hatch into both sexes. Usually weather or other conditions decide whether unfertilized thrips eggs will produce thrips. When conditions are good the female can produce eggs without going through the time consuming act of mating. When conditions are bad or food

supply is limited, sexual mating that increases different offspring that can survive in tough conditions will take place. Male thrips may not be able to pass along their genes to their sons, but they can produce grandsons that have their genes.

Pest control of thrips can include some parasites that feed on thrips, but these particular thrips parasites are limited mainly because of the small size of the thrips and where they operate. Too many parasites are too large to get into places where thrips thrive; therefore pesticides are used when thrips become an agricultural pest control problem.

Shaking or banging the suspected leaves or blossums on a flat surface will dislodge the thrips and a count can be made. They are visible to the eye, but magnifying glasses will give the person checking for them an easier number count.

Orthopterans: Cockroaches, Crickets, Grasshoppers and Locusts

In the United States, Arizona has the most number of orthopterans with two hundred and eighty two recognized species. The southwest and southern sections of the United States has the most with thirteen hundred species. Twenty four thousand species have been identified on this earth. Orthopterans like warm temperatures and many of them are an agricultural pest. The Mormons when settling in the western United States, now the state of Utah, fought the cricket called the Mormon cricket. Grasshoppers caused much devastation of crops grown for the cattle industry. Cockroaches are called a domestic insect pest that spreads contaminating diseases.

Like the Hemitera the Orthopterans only have three life stages and therefore are referred to as hemimetabolous insects. The majority of them have external wings, but there are some species in this group that do not have wings. They are also called nymphs after birth until adulthood and resemble their adults. Nymphs do not have active sex organs nor do they develop wings. Orthopterans lay their eggs outside their bodies for the most part but the cockroach Orthopterans produce their eggs inside their bodies in containers called brood chambers. These chambers are where the eggs hatch and the nymphs that hatch are born alive. The emerging nymphs hatching from eggs are usually covered with a membrane. These covers are shed and found around areas where the eggs hatch. They are referred to as cast skins. When inside these skins the nymphs are sometimes referred to as embryos and not nymphs. The nymphs and adults are much alike except for the lack of wings and some species never grow wings, but they do acquire sex organs when they become adults. Orthopteran insect nymphs go through from four to thirteen molts.

Egg laying

The orthoptera that have ovipositors use them to insert their eggs into soil or in many cases into living plants. This includes the crickets and katydids. Field crickets lay their eggs in the soil. Some katydids lay their eggs by inserting them into the space between the upper and lower edges of leaves. Katydids will also lay their eggs in rows along plant stems. The grasshoppers drill holes in the dead wood or on grass clumps and the leaf surfaces. Grasshopper females will extend her abdomen manipulating the valves in her ovipositor to make a hole in the soil then she lays her eggs. At the same time she produces a thick liquid to coat the eggs. The liquid hardens and gives some protection to the eggs. These egg pods that are buried in the soil are laid over a period of several weeks. Some of these eggs are not fertilized and in many cases the unfertilized eggs do not hatch, but when this laying of eggs without fertilization occurred in the testing laboratories the eggs hatched without males. This is similar to the aphids that require good weather and food conditions (like lab conditions) for unfertilized eggs to survive and hatch. Another trait of the orthopterans is that the numbers of segments on the antenna grow whenever another molt of nymph growth stage has occurred. Grass hoppers have

around twenty to thirty segments in their antenna when they become adults. This is about double the amount of antenna segments when the nymphs hatch. The antennae divide at the middle of the starting antennae or after the third antenna. The length of time that an orthopteron insect will live can depend on when the insect egg was laid and the conditions. Each generation will last a year, but conditions that are not favorable will cause the insect to spend time resting. If conditions are poor the embryo in the egg can take several months to hatch. This resting period can take a year depending on when it was produced. Usually the lifespan will last a year in normal conditions. The North American cockroach can take as long as seven years. Its nymph growth stage can take two hundred and twenty five days. German cockroaches take ninety five days for their nymph stage. Their adults can live for two to several years, but this depends on the species or orthoptera and the conditions that they have to live in.

The female adult has ovaries where the eggs form. The ovaries have tubes that are connected to the oviduct that leads to the rear of their body where the vagina is located. The eggs develop in the tubes and move to the oviduct which leads to the vagina where a sac called the spermataphore is located. When the eggs move down the oviduct through the vagina area they are fertilized by the sperm stored in the vagina area of the spermataphore. This spermataphore is formed in the orthopteran females and is formed in the female during the first few minutes of copulation with a male orthopteran.

The male is equipped with two testes that produce a number of sperm that are active. The male has glands that also produce a liquid along with the sperm. The females when ready for fertilization often put out pheromones. Pheromones are chemical substances put out by females that make males of the same species behave in a certain behavior. In this case the activity that is generated is mating. The male orthopteran, grasshopper, cricket or cockroaches, use their large antennae to catch the pheromone chemical molecules and begins seeking out the female. The male goes through definite searching motions that include folded wings raised and fluttering. When the male finds the female and she is still willing, he uses his tail end or abdomen which he thrusts out and under the female's rear end where her ovipositor opening for her spermathecal is located. The male has genital hooks that he uses to hold the female in position until his spermatophore with his sperm is attached to the female. The time required to do this takes about an hour.

Grasshoppers have colored hind wings that they fly around or hover over the female making courting sounds. Not all grasshoppers, but some of them. This is a further means used to attract the mating females. The mantids which are orthopteran that feed on grasshoppers and crickets, after the fertilization activity is over the female will often attack, kill and consume the male mantid unless the male is able to escape. Inside the laboratories where mantid research occurs the male mantid is in small spaces and has a problem escaping from the freshly fertilized female and then the male becomes a meal in most cases of the female mantid.

The orthopteran crichets and katydids do their feeding during the night and some can be found in cloudy weather during the day. The ones that feed during the day include the grasshoppers and others that feed on flowers which are open during daylight hours. The altitudes where orthopterans exist include mountains at elevations of eighteen thousand feet where grasshoppers with their powerful wings are found feeding on vegetation, but researchers have also found the hoppers at high altitudes with small weak wings. Usually the same species of orthopteran are found in each area, but there is some movement of different species usually spread by human beings that move insects from one continent to another. When I served in the Air Force during the Korean war as a flight attendant and load master one of our jobs was to spray the inside of the aircraft with DDT before we landed to keep any hitchhiking insects from entering our country. Nobody complained. Passengers were happy to

get the long slow flights over. The body shape and structure of the orthopterans is formed for use in their daily living activities. The mantids that feed on other insects have necks so that they can turn their heads allowing them to seek out other insects that they prey on. Their front legs are hinged with spines that allow them to grab and hold their victims. Other plant feeders use their front set of legs to gather leaves and flowers for food. The orthopterans like the mole crickets have short, strong front legs that they use to dig tunnels to live in and lay their eggs. They also use these leg spurs to cut roots for food. Some crickets called camel crickets have basket like spurs on their hind legs that they use to burrow into the sand. There are grasshoppers that exist in the southwest United States and parts of Africa that bury themselves in the sand using their legs to cover themselves without digging a hole in the soil.

Some orthopteran insects have very strong hind legs that they use to run from predators. The mantids stalk their prey and wait until they are close enough to grab them quickly, but they can also run and catch their food. Some species of orthopteran have widened hind tibia that the aquatic members use to swim with. The orthopteran body shape is used to allow them to live in certain locations, like under things: stones, tree branches and the bark of trees. They have bodies that are shaped like twigs and leaves for camouflage. Some of them have spotted wings and different colors that blend in with the environment hiding their bodies from predators and insect victims. Grasshoppers that look like certain grass stems that they cling to and hide from predators. Some orthopterans have skin cells with color pigments that can change with the surrounding foliage and blend in hiding from their predators. Some orthopterans can produce fluids that predators avoid because of bad odors or the liquids are acidic and can burn. The word *swarm* is a good way of describing locust invasions, but solitary or single locust is common in most cases. The locust is just a short-horned grasshopper. The major difference is that they tend to suddenly multiply in numbers and begin swarming. When they swarm into massive numbers they become very destructive to agricultural crops. The swarming locusts are darker and their wings are longer than the solitary locusts. The darker shade and larger wings occur along with the maturity of their reproductive organs. Once they start increasing in numbers the crowding increases and maturity and reproductive organs development.

The solitary locust when crowded will have a change in their hormones causing them to change into crowding locusts. This crowding causes the females to mature into adults with mature sex organs at a faster rate. Hormones are formed that speed up the egg maturation and the flock of locusts increases substantially. Usually good weather with abundant food for the flock will cause the locusts to become solitary, but when the weather becomes poor and food is scarce these poor conditions trigger crowding to obtain the small amount of food and this condition increases egg production by the females and large flocks instead of small solitary locust populations are formed.

These changes are due to hormone and pheromone changes in the bodies of locusts. Besides using hormones for mating, orthopterans use them for other purposes. In females an enzyme is secreted when she is giving birth that eventually dissolves the cuticle that encloses the embryo. Also a hormone is secreted that controls the number of molts that the nymphs will have during their growth to adulthood. Although the study of the grasshoppers, crickets and katydids the fact that they use sounds to carry on their existence is well known. Other orthopteran insects are believed to use sounds also, but their use of sounds is not as well known as it is with these noisy three. Grasshoppers make their sounds by moving their back set of legs across their front wings. The other grasshopper insects receive the sound through the vibrations caused when the sound waves connect with the membranes on both sides of the grasshopper's abdomen. The membranes have areas of cuticle over an air sac that vibrates when hit by the sounds. Other insects, crickets and katydids, use their hair follicles or their antennae parts to receive the sounds that cause physical vibrations.

Insect egg production (Why Insects Survive in Such Numbers)

Just as some plants produce large amounts of seeds, insects produce large quantities of eggs. It is said by several text books that most insects lay between one hundred to two thousand eggs. But some insects like the termites and bees will lay a much larger number of eggs. Some of the insects provide no parental care for their offspring. These insects have a very high mortality rate. One example of the *non care for their young* is the Australian ghost moth female that was captured and laid 29,100 eggs and when they dissected the moth they found another 15,000 eggs in her ovaries. This particular moth flies over eucalyptus trees that are their target where the emerging larvae worms feed on the tree's roots. No care is given to the hatching young therefore the number of surviving young is very low in comparison to those that die. These insects are called nonsocial insects and are expected to lose most of their young. Insects that provide for their young have very high survival rates. The social ants are one of the most productive producers of eggs and broods of new born ants. One report has it that army ants can lay a batch of eggs that has one hundred and twenty thousand eggs every thirty six days and queens of African driver ants can lay three to four million eggs every twenty five days. These females are some of the largest with up to fifteen thousand ovaries in their bodies. The queen lays eggs on a continual basis with occasional spurts of egg laying that last for a period of five to six days. Other social insects that have a complete system for caring for their young include the honey bees and termites. These high producing and rearing type of insects have specific individual insects that are controlled by pheromones usually given off by the egg laying female that prevents the care givers from laying their own eggs. These care giving insects provide the food for the egg layers and the young plus they defend the nest. This allows the queen to concentrate on only laying a vast amount of eggs.

Dispersal and Migration of Insects

About one point nine million species of animals have been named, but it is estimated that the total number of species may be three to one hundred million. The use of DNA sequences can give better identification because of the large number of differences that aren't available in observable physical differences. Only a lesser number of species can survive many of our conditions. The survivors are the species that are able to provide the populations that we have today. In order for the survivors to keep on living most of them move to areas and conditions that they can multiply in. They either migrate to their new habitats or they are dispersed to these areas where they can multiply.

One of the citrus growers that I worked with in the Yuma area came to me with his concern over the butterflies that he was finding in his newly planted citrus fields. The butterflies had just started invading his citrus seedlings. They were seeking shelter in the cardboard cylinders that covered the trunks of the citrus seedlings. This grower was concerned with the fact that these insects would lay eggs and produce worms or grubs that would feed on and destroy the tender bark of the seedlings. I had just read that the Yuma area was in the migration path of this particular butterfly that was heading north from Mexico for the summer months. The migrating butterflies were resting in the citrus, but they would and they did move on with their migration. In the coastal areas of Santa Barbara, California I have been asked by growers what to do when earwigs and crickets are found in the wrappings that are around the young tender trunks. In this case these insects were feeding on the tender bark of the citrus seedlings and these insects had to be treated. A pesticide dust, when these dusts were popular, was used when the removal of the wrappings wasn't effective. This is a somewhat common problem in some areas.

These butterflies are called Monarchs and they have migration pathways that they use to migrate from southern Canada to central Mexico. They spend the winters in Mexico. In the spring they

mate and lay their eggs usually in milkweed. The caterpillars go through their life stage and pupate. Then they grow into adults with wings that they use to fly north. Migrating insects have and use wings and they are not in search of resources such as food as is the case of insects that are dispersing. Dragonflies are some of the longest distance flying insects that migrate. They migrate between India and Africa crossing the ocean. Several birds migrate and some of the African animals have a migration schedule that they use on a seasonal basis.

When talking about the migration of insects and the dispersal of insects there is a question as to whether these two mean the same thing. Both migration and dispersal mean that the insect moves from one place to another place and the insect uses their own body to carry them or they use wind or other forms of transportation to help them migrate or disperse. Some say that dispersal is caused by the need for resources like food where as the migration movement is not caused by the need for resources. If the movement is caused by wind or other movements other than the insect energy, this is called dispersal. In many cases where insects move from one location to another they use both types (migration and dispersal). Resources, food and the insect's use of their own means of mobility, along with the winds all help in the migration and dispersal.

Some insects migrate to avoid bad winter weather when they are mating. The Monarch butterfly that I mentioned earlier that visit's the Yuma area on their way from Mexico goes to over-wintering areas and then back to its summer areas or breeding areas. With different weather conditions to go through, they use their own navigational abilities. The migrating insect must be able to overcome winds blowing against them. They do this by using their wings to fly above head winds until they find a wind that will carry them to their destination. Monarchs have been seen by glider pilots flying at an altitude of almost four thousand feet. This was high enough to overcome the common head winds at the lower elevations. The aphids, *Aphis fabae Scopoli,* climb in the air flying upward toward the blue colors; then they fly down after many hours of flight. They are attracted by yellow and green colors of the land based crops. Some researchers have described insect flight as either migratory or trivial. Short flights between crops or food resources are classified as trivial where-as migratory flights take time and persistence. *White flies, during trivial flights*, are attracted to the green and yellow wave lengths and not the ultraviolet light that attracts *migrating white flies*. The researchers have seen the same white flies doing both so there is a great deal of overlap in deciding whether it's migration or trivial flights.

The body has to have certain equipment for migration flights. The activity requires wings as a number one tool. Studies have discovered that the insect needs to exert a great deal of energy to fly up to higher levels in the sky. The insect body with abundant lipids or fats has access to more energy than the insect body relying on carbohydrates. Lipids can supply as much as eight times more energy per unit of weight than carbohydrates. Insects feeding on fresh green vegetables have lower levels of lipids than insects feeding on senescent or more mature plants like melons. White fly insects (those between three to five days old) had the longest flights and whitefly (insects those over six days of age) had less energy for long flights. The older white fly insects had muscles in their thoraxes or mid bodies that had started to break down.

When working in the Yuma area and recommending pest control during the height of the whitefly infestation on lettuce, I requested that our applicators wait until after the sun had risen and the insects were actively flying. I found that I was able to get a longer period of pest control for these fields before white fly populations built up again. After reading this I might not have killed more white flies. The migrating white flies that were not after food could have flown to other field miles away, but I killed the ones who were trivial and didn't migrate. At the time I was trying to keep the field clean of whitefly and

if the migrating white flies wanted to go do something else besides eating my field of lettuce or melons that's the way things happen. Either way I got a better and longer control by waiting till the white flies were awake and active. The studies on insect migration, dispersal and trivial flight are ongoing and new control methods continue to be found.

Dynamic migration is *directed movement* that is controlled by tides or wind, with navigation abilities not essential. The desert locust *Schistocerca gregaria* (Forskal), found in Africa is a good example of this type of migration. The majority of migratory insects fall into this category. Homeostatic migrations are two-way movements with migrants or offspring returning to specific breeding areas. Hence they need navigational abilities. The monarch butterfly is a good example of this type of migration. This insect migrates to over wintering sites and then migrates back to its summer range using navigational abilities.

One of the studies on insect migration was carried out on the good bug or predator called the Ladybug. In the nineteen sixties I was able to attend a grower meeting outside the city of Fresno, California. Two agricultural scientists did an in depth study of the Ladybug trying to find out why many captured lady bugs didn't eat insect pests and when released; the ladybugs took off flying instead of attacking the pests around them. Other ladybugs laid eggs that produced voracious crawlers that attacked the infesting bugs around them. These researchers also found that if they went to the coastal beaches of the Pacific Ocean at certain times of the year they were able to find large numbers of ladybugs along the shores. At other times of the year the Sierra Nevada Mountains had masses of ladybugs sleeping on the ground at high mountain altitudes.

So they decided to find out more about the life of the ladybug and how they could turn this into an aid for insect control. Both of these men were entomologists with the state of California. As part of their research they flew a Cessna aircraft back and forth across the San Joaquin Valley. They used the Cessna with the wing over the cabin. This allowed them to place circular netted plates outside the aircraft that would collect flying insects. The plane was flown at different altitudes to measure how high the lady bird insects were from the ground. They also took air temperatures where the insects were collected.

These two researchers recorded the following information:

1. They captured lady bug insects at altitudes of as high as ten thousand feet.
2. When temperatures reached fifty five degrees Fahrenheit or below, the ladybug insects were not flying. According to the researchers the ladybugs closed their wings at this temperature and fell to the ground.
3. They did this research at different times during the year and were able to find ladybugs throughout the year during hot and mild seasons of the year as long as the temperature was over fifty five degrees F. During the spring the direction of flight was toward the ocean and during the late summer and fall the direction was toward the mountains.
4. The ladybugs were moved by the prevailing winds. Winds across the valley blew toward the mountains during the summer and fall months and toward the ocean during the spring and early summer months

When the researchers netted ladybugs on the ground the lady bugs were examined and weighed. The sleeping ladybugs in the mountains were extra heavy with high amounts of fat. The lady bugs at the sea shore had much lease fat and their protein levels were higher than the sleeping ladybugs in the mountains.

The ladybugs captured in the mountains were fed water which they wanted as they came out of their sleep. They didn't attack the insects that they normally feed on when the water was available. By keeping water from them the researchers noted that the ladybugs began attacking and feeding on

the other insects. This may have cured their need for water. After a length of time that the ladybugs were penned up with the other insects that they fed on, it was noted that the ladybugs began mating and produced eggs that hatched into larvae and these larvae also began feeding on the other insects.

The researchers gave us the following reasons for the high number of ladybugs in the air, in the mountains, on the valley floor and on the sea shore:

1. During the spring of the year the San Joaquin Valley has high populations of ladybug adults and ladybug larvae feeding on insect pests like aphids, scale and mealy bugs.
2. As many of the adult ladybugs run out of insects to feed on, they start flying up into the air to find more insects to feed on. They are seeking a food resource and this could be classified as Dynamic migration.
3. They fly at higher and higher altitudes and the prevailing winds that are blowing toward the eastern Sierra Nevada mountain range carry the flying adult ladybugs east into the hills and mountains.
4. When temperatures drop below fifty five degrees Fahrenheit the ladybugs stop flying and drop to the ground. They continue to do this each day traveling as high in the mountains as ten thousand feet. 5. The ladybugs are still hungry and because of the lack of insects like aphids, scale and mealy bugs at the cooler higher elevations they switch their diet to the nectars of flowers and plant leaves. This change in diet increases the weight of the aphids and they start to hibernate and sleep.
6. As spring approaches things warm up and the ladybugs awaken and start looking for water. They have lost the excess weight and begin flying again. The prevailing winds are blowing away from the mountains and the ladybugs are over the valley and as the temperature drops to fifty five degrees they close their wings and drop to the ground.
7. On the ground they wait for the temperature to rise above fifty five degrees F. and continue flying. If they find other insects to eat in the place of water they consume enough protein to become sexually active and they end up mating thus producing eggs that become larvae that begin feeding and controlling the pests that exist on the growing crops in the valley.
8. The adults continue to fly and be carried clear to the Pacific Ocean shores and sea where they drop to the water or shore when temperatures again drop below fifty five degrees F.

Some of the ladybugs do not go through this flying and dropping. They exist on the land and stay there throughout the year feeding on insect pests. People go to the high areas to collect these ladybugs that are hibernating. Some people sell the ladybugs as predators to farmers and people with gardens. These harvested ladybugs will still attempt to fly away and the people who obtain them either by purchasing them or collecting them may lose them if they are still looking and finding plant nectars and leaves instead of insect proteins.

Weather and insect dispersal

Weather has a great deal to do with dispersal of insects. One study done by a group of scientists at Pennsylvania State University, examined fossilized leaves in the northern Bighorn Basin that dated back fifty two to fifty nine million years ago. They identified some plants and the feeding damage done to them by insects. The damage to the plants was not due to the plants where the feeding occurred. The feeding was due to the increase in warmer temperatures that in turn built up the insect levels. The scientists blamed the feeding damage on the warmer temperatures that drew these particular warm climate insects to this area. This feeding occurred during a period of high temperatures sixty five million years ago in an area that now has very cool temperatures and a lack of warm-

weather-crop destroying insects. The insects were identified from their fossil leaf feeding damage as tropical and subtropical insects. The insects had migrated due to the warming in this location that is in the present state of Wyoming, a fairly cool area. Some scientists have written articles that mean that: *Because of the evidence of this plant leaf feeding damage to these fossil ancient plants, "earth warming" could be a reason to be concerned with insect damage that can occur from earth warming.* Earth warming has turned into an argument that will go on for some time. People in our industry that control insects may get into the argument at any time. Another insect that farmers have to deal with that needs to disperse when food starts to run out due to increased populations is the aphid insect pest. Aphids that encounter diseases, bad climates, starvation etc. can survive if they have the right set of genes. The greater the mix of genes the greater the chances of survival for aphids with the right gene mix. Just the fact that the sexual mating of male and female aphids can produce an egg that will survive the tough winter increases the chances of aphids' species survival. The sexual union produces an egg and a mix of genes both vital to the survival of the aphid species in different atmospheres.

When populations reach higher numbers than the food supply can't feed, the aphids **disperse** to other nearby fields for their food source; but when the area where the aphids are living starts cooling off and food becomes scarce the aphids begin to **migrate** to other areas where food is available and better living conditions exist. In order to migrate, the young, which carry out the migration movement, have to go through a change. The bodies of the aphids will go through a change caused by the conditions of less food and or a change in the weather. Their new young will consist of male and female embryos. The new embryos will be contained in egg shells the eggs can protect the young male and females from the harsh weather conditions and reduction in the food supply. Under some severe conditions the embryo in the egg shell may go through a protective dormant stage to further be protected from the harsh conditions. Changes in the environment and the crowding of aphids can results in loss of feeding sites. The loss of feeding sites produces a stimulant in aphids that will produce the new born young with wings when they become adults. Both male and female can grow wings because it is an inherited trait, but conditions have to stimulate the need for wings and one of these stimulants for wing growth is when food is in short supply. The winged aphids move to allow the aphid population to survive. The winged aphids are not very strong flyers, but with the aid of winds they can move long distances in a relatively short period of time. Winged aphids can fly at speeds around 1.5 miles per hour when the air is still. As the night and darkness occur the aphids fly up to 3000 feet where the winds have been studied that can carry winged aphids for a distance of 250 miles in 9 hours. The winged aphids land during the early dawn to avoid dangerous updrafts caused by the warming sun on the earth's surface.

As the aphids prepare to land they aim for the leaves that reflect the green and yellow tinged light wave length given off by actively growing or aging plants. Both of these types of leaves are either taking in sugars from photosynthesis (young shoots) or producing and sending out sugars (mature leaves). Both areas provide aphid nourishment. The edges of fields seem to attract the descending aphids and this is one reason that crop border strips are used as aphid trap crops by some growers. Aphids can be found all over the field and this is because the aphid females engage in "trivial flight". Winged aphids find a suitable plant to feed on using the following clues: taste, visual and chemical. They fly short distances, testing plants that they land on by probing with their styllets. As they fly from plant to plant aphids lay more female aphids and spread diseases carried on their mouth parts throughout the field.

Aphids defend themselves to a certain extent. Aphids will kick at an attacker and try to discourage any attack. The aphid will pull up their mouthparts from the plant that they are feeding

from and walk away and this includes jumping off of the plant. Some species of aphids can also spray out a waxy solution on their attacker. During these defensive actions the aphid will emit an alarm pheromone alerting the surrounding aphids to the attack. Some species of plants have been found to put out the same pheromone to drive aphids off of their leaves. The aphid alarm pheromone is emitted in short bursts by the aphids whereas the plant pheromone is constant; therefore the aphids are not usually alarmed by the plant pheromone. Researchers have tried using plant pheromones to mimic aphid alarm pheromones to protect crops, but to date without success.

As the fall months with cooler weather and shorter days approach a change in the female aphids takes place due to the increase in darkness caused by shorter daylight days. The increased darkness releases a hormone in female aphids that causes them to asexually give birth to sexually active female aphids. The exposure to darkness has to be experienced by the new mother and her grandmother (two generations). When the sexual female aphids are ready to be fertilized they send out a pheromone that attracts sexually active male aphid adults. The sexually active male adults are born asexually by the females that give asexual birth to sexually active females because of the increase in darkness. The adult sexually active females and males aphids also have wings.

Controlling Insect Migrations and Dispersal

The word dispersal is described as scattering that produces a distance between the insects. Migration is the movement from one area to another area. There are discussions on these two words (migration and dispersal), but when it comes to insects that cause problems in agriculture any crop damage that occurs is investigated and studied for methods of control. The state, county and country uses several methods to lesson the dispersal or migration of crop insect pests. Vehicle inspections at borders are carried on seven days a week. Insect pest traps are maintained to alert districts where insect pests may become a problem resulting in area control methods like pesticide area applications.

The bacterial disease that the Asian citrus psyllid carries and infests citrus trees is called, HLB or Huanglongbing. It was first found in the month of March in Southern California. The tree was destroyed to keep the disease from spreading. It can be spread in a number of ways: (1) an infected psyllid insect could fly into the area and infect a seedling citrus tree; (2) a person taking a bud from an infected tree and grafting it to an existing root stock; (3) an infected seedling could be illegally carried into the area and planted.

The government agencies are monitoring for Asian citrus psyllid infestations In California and Arizona. They visually check the citrus groves and also place yellow sticky cards in citrus trees that trap adults. When the authorities find an Asian citrus psyllid they quarantine an area that is twenty miles from the site of the find. Plants and fruit cannot be removed from the site.
http://www.cdfa.ca.gov/plant/pe/interiorexclusion/acp_quarantine.html is the web site for California that you can notify. Until scientists find a cure for this problem all citrus growers and nurseries are asked to assist in this program.

The psyllid has been found in subtropical Asia, Afghanistan, Saudi Arabia, Reunion, Mauritius, locations in South America and Central America, Mexico and the Carribean. This particular psyllid (Asian Citrus Psyllid) was first found in the United States in Palm Beach County in Florida on an orange jasmine plant in nineteen ninety eight. By the year, 2001 it had spread through thirty one counties in Florida. Since then this insect has been located in Texas, Louisiana, Georgia, Mississippi, Alabama, South Carolina, California, Arizona, Hawaii and Mexico. It is spread by nursery stock of citrus and ornamentals like the orange jasmine.
In March 2012, huanglongbing was found in a citrus tree in Southern California, and this tree was destroyed to prevent the spread of this disease. Everyone's assistance is needed to watch for additional

infected trees. The disease may have already spread from this initial infection in Los Angeles in the bodies of psyllids to other citrus trees, or it may come into the state in an infected citrus tree or other host plant, illegally imported or smuggled into the state. It could also arrive in the body of an infected psyllid that flies or rides on a plant into California from places such as Mexico where HLB and psyllids are found together. The tree that was found with HLB in Los Angeles is believed to have been infected through grafting a bud from another infected tree. Budding is done by taking plant tissue from one tree and inserting it into another to form a new branch.

An early symptom of HLB in citrus is the yellowing of leaves on an individual limb or in one sector of a tree's canopy. Leaves that turn yellow from HLB will show an asymmetrical pattern of blotchy yellowing or mottling of the leaf, with patches of green on one side of the leaf and yellow on the other side. Citrus leaves can yellow for many other reasons and often discolor from deficiencies of zinc or other nutrients. The pattern of yellowing caused by nutrient deficiencies typically occurs symmetrically between or along leaf veins.

Government Methods use insect trapping to fight migration, dispersal and trivial flight. Isolated pockets of Maricopa County in Arizona have occasional outbreaks of California red scale. The Yuma County Citrus Pest Control District and Arizona Department of Agriculture have programs to monitor for California red scale. Then they abate the infestations that they have discovered. This manner of discovery and control is done by insect abatement districts. They use a grid network with pheromone traps to detect the presence of male California red scale. Once the scale males are detected scouting of the area is used to find the exact location of the infestation. Then the control efforts are carried out by these state, county and district abatement operations. These methods have been very affective.

Another example of an insect invading an area in the United States by dispersal is the Asian Stink Bug that was first spotted in nineteen ninety and is now found in thirty nine states. These stink bugs are now considered to be a pest in several growing crops and they have become a household pest in many cities. The stink bug is expected to increase in populations by sixty percent. The smell given off by squashed sting bugs is especially odorous especially in homes and other occupied buildings. In California the University of California Agricultural and Natural Resources arm claimed that this stink bug is one of the worst invasive pests they've had to deal with. Plant and Animal Health Inspection Service is thinking about introducing a small wasp called "trissolcus" to control this stink bug population.

The need for the use of pest control is often based on the migration and dispersal of the insects. The control methods are usually not based on producing a "pest free" situation. When insect damage reaches levels that cannot be tolerated control methods are initiated. The damage done by a particular insect pest is determined and methods of control are applied. Trapping can be done either by attraction methods using pheromones or food or physical methods using sticky materials. They also use sweep nets to give us the number of insect pests. The insect population and life stage whether adults, eggs, larvae or nymphs are used to know what damage levels we can expect. Knowing the kind of insect plus what the damage that this population can inflict is taken into consideration. In some cases the damage that is discovered can be used as a level when infestation treatment is started.

The presence of insect predators whether they include insect diseases or other animals that attack the particular insect pests should be taken into consideration. Some control methods can be timed to allow the lady bugs and even birds to control the insect pests. In some cases after trapping or the use of other infestation methods have been used, release of an insect predator is started.

Insect Dormancy and Diapause

Although insects have survived for a great many years by migrating and dispersing from one area to another to continue their stay here on earth they also have the genetic given technique of going into dormant stages to avoid conditions that can end their ability to live and damage the human needs of existing on this earth. Several of the insect pests only have to disperse to nearby orchards or woodlands where they can gain protection from adverse weather. Monarch and painted lady butterflies migrate long distances to avoid weather conditions that can kill them rather then going into some kind of dormancy. Many of the insects go into dormancy stage to survive very cold temperatures. The insects go into a state of diminished physiological activity. Their body functions slow down and do not require the normal temperatures needed to stay alive. This reduced living stage is called "diapause". The diapause state can occur in all of the life stages of an insect. It occurs in the egg, nymph, larva, pupa or adult forms of insect life stages. This stage, diapause, is when a slowing or stoppage of growth occurs or the stoppage of sexual activity in the adult stage of the insect's life. Diapause can be a period of suspended development as well as a period of suspended physiological activity.

Some insects can survive at temperatures as low as minus ninety four degrees Farenheight. Usually this is about the lowest temperature that natural environments reach. Insects that have this ability are divided into two different classes: insects that are freeze-susceptible and insects that are freeze tolerant. Freeze susceptible insects are able to avoid freezing by using antifreeze materials called cryo(freezing) protectants. Automobiles are treated with antifreeze which is a cryo-protectant to keep the water in the engine from freezing. One of these is called ethylene glycol. The freeze susceptible insects are able to produce these chemicals in their systems and thus prevent their systems from freezing. They are likely to freeze if they didn't have these chemicals in bodies.

The *freeze tolerant insects* do not have the antifreezing materials in their systems, and therefore the water in their systems can freeze and it does. The water in their systems is frozen, but the freezing process in these particular insects forces water out of their systems as it freezes; and therefore lowers the level of the freezing point. Physics tells us that: smaller amounts of water freeze at a lower temperature level than larger amounts of water. Both systems work to reduce the freezing damage to the insects, but they are still subject to damage from other conditions including: their size, moisture, temperature, stage of growth and the type of insect which is in this case the species of the insect.

When it comes to the *size of an insect* and freezing to death, the larger insects are the ones at a disadvantange. The larger insects have more room in their bodies that holds water and the more water in the body increases the freezing level. The smaller insects like ants have less room to hold water and they can exist in freezing weather when compared to the larger insects like grasshoppers. When insects are in the small life stage of the egg they contain less water because of their size and therefore have less space for water. The first instar stages of insects like the larvae or crawlers are smaller and contain less water.
Small size is better under freezing conditions. "The bigger they are the harder they freeze."

Being wet is bad for insects when temperatures drop. An insect that hasn't found food and has an empty stomach will be able to exist in freezing temperatures because food in the insect's body attracts more water than an empty stomach. These protective measures don't gaurantee a long life if the cold condition lasts for a long period of time. After a certain length of time in freezing conditions, the insect is likely to die. So the length of freezing time can overcome the insect's protection from freezing to death. The egg is smaller than the larvae and adult stages and this gives the smaller egg that holds less water a longer survival time in freezing conditions. Pupae and egg stages require

very low quantities of food and therefore the insect in this form of life stage can exist longer in cold conditions. The cocoon and other pupae structures built by insects will give some protection from freezing conditions. These structures cover the insect's living body that is buried in several inches of soil.

The environment that the insect is in during the different seasons of the year change and may help the insect survives. *Snow itself can provide a protection to the insect*. It becomes a form of insulation. Insulation raises the temperature. This is especially true of light fluffy snow where freezing temperatures are raised to warmer levels due to the added insulation. Some insects can be found living on the south side of trees where it is a little warmer. Dry leaves and dry soil can become a haven for insects seeking shelter from cold wet conditions. Any increase in freezing, wet conditions can suffocate the insects.

There are statements out of the University of Florida Department of Entomology and Nematology that one of the longest insect dormancy or diapause occurred in Nevada. A yucca moth under artificial conditions as prepupa emerged as a living adult insect after nineteen years. The yucca moth had some unnatural conditions. This prepupa were housed in sealed cardboard boxes that were subject to various temperatures and air moisture levels with subdued light and no direct moisture from rainfall. These conditions may have been the reason that the insects in this stage of growth couldn't break their diapause. Another report stated that the invertebrates (animals with external skeletons called "tartigrades) were found in dried moss and were alive when they were moistened after one hundred and twenty years. Some insects like the golden prestid need one to three years just to go through their life cycle. There are reports of insects having a delayed emergence from structural timbers after twenty six years.

Some insects like the moths and butterflies have pre pupa life cycle stages. One of the known insects, cicada, has a dormancy period of seventeen years during the larval and pupal periods of growth. You might have turned over a rock or chunk of wood in the dry desert soils during the dry summer conditions. This is where insects hide deep enough in the soil to exist in these harsh conditions. Butterflies of some species can survive in the winter months by staying in snow covered shrubs. The insects that form cocoons or in some cases nests can survive the entire cold winter season.

When mild weather returns to the area where these insects have gone into diapause some of the insects will automatically start their normal life's activities, but some species need more *time* for a change back to normal conditions. Some insect species need *food or cold weather* to break the diapause stage. There are species of mosquitos that lay their eggs on dry soil and they need *water or flooding* before the eggs that are in a diapause conditon will hatch. Their lavae need water to exist and swim in. Mosquito eggs require water to hatch in. In other cases some cutworms require a *certain length of time* to occur before they will hatch in spite of how good or bad the conditions are.

Diapause occurs in insects when certain environmental factors join together and act on the insects. These factors include: length of time, temperature, moisture, light and food. These conditions act on the nervous system and the endocrine system that produces hormones that control the insect's organisms. These insect organs keep the insect alive when it's in diapause and even in an active life stage. Very often we cannot use pesticides to kill insects that are in diapause. Their systems aren't active enough to take in the pesticide.

Another method used by insects to survive when freezing temperatures occur where they happen to be is the use of a torpor condition. The insect becomes immobile or completely still. It's a stage unlike diapause in that the insect only stays asleep or immoble for a shorter period of time then when the insect is in diapause. This usually occurs at higher altitudes and near the north and south

poles. As the temperature drops like in the evening crickets freeze solid. When it warms up the insect resumes it normal activities.

Some insects like the lady bugs go into this torpor like condition when they migrate to areas in mountains where they group together gaining heat from the other ladybugs. Often the snow in the higher altitudes covers these huge colonies and their combined bodies give off enough heat to keep them from freezing to death.

Evolution Of insects

Evolution points out the drawback to size. One of the insects that existed two hundred and ninety nine million years ago was a griffin fly. It was one of the biggest insects known. It had a wing span of twenty eight inches. The fossil was found in nineteen thirty seven in Kansas. It measured seventeen inches from its head to its tail. Another insect displayed in the Harvard Museum of Natural History had a wingspan of twenty seven inches. It was discovered in Oklahoma in nineteen forty. Both of these insects didn't go extinct for a period of over one hundred million years.

There were two major radiations on this earth. Winged insects were hit with a major radiation in the period of 359 million years ago until 299 million years ago and another radiation period during 299 million years ago and 252 million years ago. The survivors evolved during the following period of 252 million years ago until 201 years ago into the insect orders that are here today. The insects that survived did so by diversifying. The changes in their bodies allowed some of them to survive the damaging conditions that occurred as the earth changed. Large insects didn't survive as well as the smaller ones did. For the most part insect fossils are used to study when their ancestors where on this earth and which insects have relatives that are still around. In order for a fossil to last certain things had to happen. The fossil had to be rapidly buried or entombed. The fossil had to be free of disturbance and free from any oxygen. It should be covered with sediment or other forms of protection. It must be free from any disturbance like erosion. The best places for fossils are at the bottom of lakes or seas. Fossils need to be protected from any disturbance and this includes temperature, moisture and air. Certain parts of an insect's body can survive better than other parts. Wings are one of the fossil parts that hold up well and they are also used to identify the insect as to what age or time period it existed. The other arthropods like the centipedes, millipedes, scorpions and spiders are often grouped together with insects, but the deciding difference is the six legs that insects have and this is evident when comparing fossils.

Fossils can be made by mineral rich water filling the space left by the dead insect in the wet soil. As the water evaporates the minerals that fill the space take the form of the insect's body. This can give us many of the signs needed to identify the long dead insect. Some elements like carbon can form identifying molds of the insect. Resin or amber that is plant material for the most part is the popular fossil forming material. Other small creatures like bacteria, fungi and other animals supply resins. Some of these resin formed fossils date back two hundred an fifty million years.

Fossils that are cockroach-like were found between 295 million to 354 hundred million years ago. These cockroaches differ in that they had ovipositors that they used to attach eggs to surfaces. The first modern cockroaches appeared 65 to 145 million years ago. Grasshoppers which are orthoptera species identified by their hind legs on the fossils were formed 299 million years ago. Orthoptera are an ancient order that still exists today. In 2009 DNA studies on the beetles and maps of beetle evolution claimed that beetles may have originated 299 million years ago.

Back 270 million years ago the beetle that has leather like wings covering their abdomen and now called the coleoptera beetle existed. They had antennae with thirteen segments. Their genitalia or sex organs were internal. In this same period the true bugs existed. These are called the Hemiptera

and they now include insects that do not have a pupa stage and their juvenile stage is called their nymph stage instead of the larval stage. Aphids are in this group. This was 201 million to 252 million years ago. In the 200 million years ago period the first flies and true dragonflies appeared. Thrips also appeared at this time.

Between 145 and 201 million years ago the major predator of insects which are birds appeared. Insects with large wing spans started disappearing. They were too slow to escape the birds. In the short period called the Paleogene, 56 million to 65 million years ago, the first butterflies appeared. Butterflies survived by having huge populations. Insects with wings could use their wings for feeding on vegetation. At the same time that wings were used to find and feed on vegetation the predator insects evolved to seek out the other insects that they fed on. Both the hunter and the hunted insect had to develop wings that could fold and hide them from flying predators and predators that could fold their wings and seek out the hiding plant feeding insects. All of this fighting to survive by both the predator and the insects that feed on plants has produced insects that dominate the insect world. Insects account for eighty to ninety percent of all animal species. Forty to sixty percent of all insects go through complete metamorphosis. Before 208 million years ago, fossils record insects that hatched from their eggs looking very much like their adults only smaller and they grew by stages where they emerge from their exoskeletons growing larger ones to replace the old. Today aphids use this method of growth.

The bodies of new insects (the ones that evolved 208 years ago) when they emerged from the eggs were shaped like worms and they crawled instead of walking on six legs like insects that don't go through four life stages. We call these insects' crawlers or larvae. They have one major advantage when compared to nymphs in that they do not compete with their adults for the same food. The adults may be predators and feed on other insects while the larvae feed on plants. Or the larva may feed on other insects as predators and the adults feed on plants.

After they go through a certain amount of molts where they grow then shed and then grow a new exoskeleton they enter another life cycle where they activate the cells that they gained when they were inside the eggs as embryos. They go through the pupa stage where these cells grow into wings, other adult body parts and sex cells that the insect uses to mate and produce more eggs. They have four stages that are different in the food they may need and the activity they may need to go through to stay alive. This form of growth has several benefits and agriculture gets some or these benefits when much needed predators are produced, but agriculture can also lose when insect pests develop. Pest control advisors and pest control applicators have to stay ahead of the insect chromosome changes that are out there.

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