Unit 15 in Entomology

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Unit 15: medical entomology.

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The objectives in this unit are to describe the different types of medically related effects caused by arthropods, both direct and indirect, to define the terms associated with disease transmission, and to describe the general characteristics of the seven diseases covered, including the vector, where in the world it is a problem, the disease symptoms, how it is treated and controlled, and the type of disease.

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Arthropods and insects, in particular, cause many medically related effects. Directly they can cause dermatitis and allergic reactions. But indirectly they can pass on diseases that can be debilitating and sometimes fatal. Throughout history, arthropods and insects have affected and infected mankind and animals with everything from minor afflictions to major diseases that have caused catastrophic epidemics. In this unit we will investigate the interaction of arthropods and insects with animals and mankind through direct and indirect means, as well as reviewing their use as forensic evidence. Please read your textbook readings to familiarize yourself with the terms associated with medical entomology.

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We'll begin our discussion with some direct host reactions to arthropods. Some direct effects, such as pain and suffering, are difficult to measure, but some quantifiable, economic effects include mechanical reactions (including dermatosis, dermatitis and itching), exsanguination (which is the loss of blood or annoyance), myiasis (which is where dipterous larvae invade the living tissue), toxins and paralysis (including envenomization), allergic reactions (which leads to anaphylaxis), and entomophobia (which is the psychological fear of insects). Let's take a look at each of these direct effects in more detail.

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Mechanical reactions: one causative agent of a mechanical, itching, reaction is a mite infestation. One mite, in particular, is the agent of scabies in humans and sarcoptic mange in other animals. The scabies mite is an obligate parasite, meaning it must feed on a host in order to complete its lifecycle. After mating, the female mite will burrow under the skin and lay her eggs. She secretes substances that trigger an allergic reaction in the host that results in painful itching. This mite can be passed through close contact between hosts and can live for 36 hours outside of the host. Sarcoptic mange found in animals is basically the same as that in humans. Most animals, including cattle, pigs, horses, and dogs, experience the same dermatitis, leading to weight and hair loss. Mange mites have been recovered and described from different animals, but it is unclear if the mites are species specific. Some mites show a preference for a certain species of host, but the specificity of the host is not absolute. The photos below show a dog infected with mange mites and on the right is a picture of the Sarcoptes mange mite.

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Mites in the family Trombiculidae are commonly referred to as red bugs or chigger mites. The life cycle of most North American chiggers ranges from 50 to 70 days. Once the egg hatches, the larvae emerges with six legs, yes, larval mites do have six legs, they don't get their fourth pair of legs until they molt into nymphs. The larvae immediately seeks out a vertebrate host. Larvae do not burrow into the skin. They firmly attach to the skin of the host and inject a digestive fluid that causes skin irritation. Once the mite completes feeding, it will fall off of the host, leaving the characteristic red skin irritation. There are many home remedies for chigger bites including vinegar, bleach, ammonia, clear fingernail polish. None of these are really effective because the chiggers do fall off when they finish feeding; they don't burrow into the skin. If you notice in the picture on the left-hand side, this was a laboratory technician that was mowing the lawn and got into some chiggers that were in Spanish moss, and you notice the severe skin irritation that was caused by these chigger bites.

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Another direct effect of insect feeding can be exsanguination, or blood loss. You've learned about the

different mouth adaptations for feeding. Well, one mouth type is rasping. Raspers, like the horn fly, serrate the host's flesh with their mouthparts and then lap up the blood that flows from the wound. They want the blood to flow freely, so the insects, many times, have an anticoagulant in their saliva so the blood does not clot. The bites are very painful and the blood loss can be significant. Some results of feeding of this type can be weight-loss or a reduction in milk production in dairy cows. Horn flies, as seen in the picture below, can be quite irritating to cows, especially if they are penned in and cannot run away or get away from the biting flies.

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Another direct effect is myiasis. Fly larvae may invade and feed on living tissues of livestock and other animals including rabbits, squirrels, dogs, and humans. This is known as myiasis. We have previously discussed the bot fly of squirrels and humans. The bot flies do fit into this category. Complications animals must deal with are debilitation, which include pain and swelling, secondary infestations of other insects, and secondary microbial infections. The fly larvae must have access to the outside in order to breathe, so they create holes in the flesh of the host. The holes and tissue damage caused by the myiasis cause economic damage because it reduces the quality of the hide by leaving holes. In this photo, you can see the warbler, and you can see the exit wound that it was pulled out of. So you can see the large hole that would be left in the hide that if the animal is still living could cause an infestation of another insect or cause an infection, or if the animal is dead, reduce the value and the quality of the hide.

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Myiasis is generally one of two forms: obligatory or facultative. Obligatory: the parasite depends on the host for completion of a certain part or parts of its life cycle. One example is the bot fly we have previously discussed. Facultative: the parasite is generally free living but can utilize a host in certain circumstances. One example is urinary myiasis. This is caused when something like a rat tailed maggot, like the one pictured below, from contaminated water enter the urethra of a human host. Facultative myiasis in humans is not very common and it's not as common as in other vertebrate animals. For example, if a rat tailed maggot were to enter the urethra of a human, it would have to be because that human maybe passed out in an area where there was sewage or where there was contaminated water. Although rare, this type of myiasis has been documented by the medical community.

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So how does an animal become infested to begin with? There are several ways. First, some flies lay their eggs around the mouth, legs and other body parts of the host. After laying the eggs, the adult fly will annoy the host, causing the host to lick the area of deposited eggs, thereby ingesting them. The eggs hatch in the intestinal tract and develop to the pupa stage that is excreted with the host's waste. The pupa then burrows into the soil and waits to emerge as an adult. Second, other flies lay their eggs on the hair shafts of the host. The larvae hatch and travel to the skin and burrow into the host. The larvae travel under the skin, making its way to the back of the host. The developing larva is known as a warbler, because it cuts a hole through the hide of the host for respiratory purposes and for exit when it reaches the pupa stage. The pupa falls to the ground where it burrows into the soil and awaits emergence as an adult. As mentioned before, this photo is intestinal myiasis. These bot flies were found in the stomach and intestines of a horse.

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A third way an animal may become infested is by the insect hitching a ride. Dermatobia hominis is known as the human bot fly. This bot will parasitize other vertebrates including cattle, swine, cats, dogs, and horses. It's found in Central and South America and Mexico. The chances of being infected when traveling in these countries is highly unlikely, but not impossible. The adult bot fly captures another dipteran fly, usually a bloodsucker such as a mosquito, and then glues its eggs along the abdomen of the carrier fly. The eggs are glued with the anterior end of the egg facing down because this is how the larva hatches from the egg. When the mosquito is taking a blood meal from its host, the newly hatched larva penetrates the skin of the host and sets up residence. These particular maggots remain in the same place so they don't wander. Once the larva is mature, it drops to the soil and waits for pupation. The entire life cycle takes three to four months. If you take a look at the photo below, this is a human bot fly warbler found in the scalp.

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Another direct effect is envenomization and allergic reaction. The venom of most arthropods and insects do not cause death in most humans or animals. Some, however, are extremely sensitive to the proteins in the venom and may have a severe allergic reaction that results in death. This hypersensitive response is known as anaphylaxis. Human deaths from insect or arthropod bites or stings are usually contributed to the hypersensitive reaction rather than from the direct effect of the toxin. Another reaction may be triggered, not from a toxin, but from the cuticle or frass of an insect. This allergic reaction in hypersensitive individuals may also result in anaphylaxis, or ultimately, death. Some examples of venomous arthropods and the source of the venom include spider bites, scorpion stings, Hymenoptera stings, Lepidoptera larvae with urticating hairs, Coleoptera, including blister beetles that make painful blisters that can even kill horses if they're ingested, and Coleoptera, including stored product beetles which cause itching or respiratory problems from contact with the frass. Another source, which has been in the news recently are from cockroaches. It has been found that cockroach allergens, including their molted exoskeletons and their frass, can actually trigger asthmatic attacks in children.

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To get a closer look at envenomization, let's look at some examples of venomous arthropods. First off we're going to look at urtication. Some Lepidoptera larva have urticating hairs that produce burning and itching direct effects when passively touched. The tips of poisonous spines break, releasing poisonous chemicals or the spines are actually injected into the skin when forcefully contacted. Only the larval or caterpillar stage have these poisonous scales.

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Another example of venomous arthropods are stinging arthropods. Many arthropods, including spiders, scorpions and hymenopterans, have defensive sting organisms. In insects, the sting is a modified ovipositor. Generally a sting reaction results in redness, swelling and local pain, but some people are hypersensitive and a sting may result in anaphylaxis. In the photos above, you can see some illustrations of the different venomous arthropods including black widow spiders, fire ants, brown recluse spider, honeybee, scorpion, and a polistes paper wasp.

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Our last example is blistering. Blister beetles in the order Coleoptera cause irritation with possible skin blistering by the toxic chemical cantharidin. This blistering occurs when contact is made with a crushed beetle. Although the toxin content of cantharidin in each blister beetle varies, if enough beetles are trapped in hay as it is harvested and is in turn ingested by horses, then the amount of cantharidin could cause death. In the picture above, you can see a utility worker who was hit on the back of the neck by a blister beetle and then subsequently smashed the beetle against his neck. You can see the blistering effects, which are quite painful, and in fact, cantharidin has even been used in the past as a wart remover because it blisters over the wart and causes the wart to flake off.

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The last direct effect we'll discuss is entomophobia. Entomophobia is the psychological fear of insects. Many people fear insects, but some have an irrational fear. This fear may lead to psychological problems, such as delusory parasitosis and entomophobia. Delusory parasitosis is when a person is mentally sure that insect infestation is real when in fact it does not exist. This condition can even bring on physical symptoms including welts and skin irritations. Entomophobia is the general fear of insects or of becoming infested with something, and this may bring about stress and high anxiety in people. This result in careless use of insecticides in and outside of the home, on pets, on children, and even on themselves. In fact, some people go so far as to put all kinds of chemicals on their bodies, thinking they're trying to alleviate some sort of infestation, when in fact all they are doing is burning their skin. When they arrive at the doctor's office, they actually have chemical burns because they're trying to rid themselves of an imaginary infestation.

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Now that we've covered some direct effects, we'll move on to some indirect effects. Disease

transmission is the most important indirect effect, so we'll begin with defining some important terms. Epidemiology: epidemiology is the study and applied ecology of disease transmission where all factors of the natural history of the disease and the vector are of interest. Vectors are all classes of arthropods that have the capability of transmitting pathogenic organisms to its host causing minor and major debilitating diseases. The host generally houses the pathogen through one or more of its life cycles, specifically the infective stage during active transmission by the vector. The pathogen is the organism that is passed by the vector and causes the disease. Vertebrates that can house and maintain the pathogen during benign and infective stages of the pathogen's life cycle, even when active transmission is not taking place, are termed reservoirs. Just as an aside, arbo, as in arbovirus, stands for arthropod borne, so if something is considered to be an arbovirus then it is vectored by some sort of arthropod.

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Vectors must feed more than once to insure that a complete blood meal has been taken for the development of the eggs. The vectors blood meal source is also important for the life cycle of the pathogen's development. The frequency that the vector feeds between hosts increases the chance that the pathogen is acquired and passed on to another host during feeding. During and after feeding, vectors must also have the correct internal anatomy and physiology to support itself and the life cycle of the pathogen. The adult stage of the vector has to be as long, if not longer, than the developing pathogen to ensure that the pathogen is transferred in its infective stage. This includes environmental factors, such as overwintering through the winter, or dry season, and estivating over hot summers. Three things are needed for most disease transmission: a competent vector, a host, and the pathogen. Depending on the pathogen's life cycle, a fourth entity necessary for disease transmission would be a reservoir.

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Mechanical transmission is where the arthropod acquires the pathogen by passive means. An example of this would be a house fly landing on an area contaminated with a pathogenic organism. The organisms adhere to the tarsi or other body parts of the fly and when that fly lands on another substrate, such as an eating utensils and food, the organisms would fall from the fly and would be left behind to be ingested by the host. Cyclo-propagative transmission is when a pathogen is delivered by deliberate means and the organism goes through cyclical changes in the body of the arthropod and/or its host. Malaria, transmitted by mosquitoes, and chagas, transmitted by hemipterans, are excellent examples of this type of transmission, because it multiplies in the vector and in the host. Cyclo-developmental transmission is similar to cyclo-propagative with the exception that the pathogen does not multiply in the arthropod. Elephantiasis is caused by an obligate filariases that is in the mosquito, starting with the microfilaria to the infective stage, then delivers it to the host where it multiplies. Propagative transmission has no cyclical changes but multiplies propagativly only. The flea produces the bacterial organism Yersinia pestis, which is the causal organism for the plague. Lice produces a bacterial organism, Borrelia recurrentis, that is a causal organism for relapsing fever. Yellow fever is a virus produced by mosquitoes. These are just a few of the examples of these types of transmission. So let's briefly review these: mechanical is where the arthropod gets the pathogen passively, cyclo-propagative is where the pathogen is delivered deliberately and the organism has cyclical changes, cyclo-developmental is similar to cyclo-propagative except the pathogen does not multiply inside of the vector, propagative has no cyclical changes but multiplies propagatively only.

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Now that you're familiar with vectors, pathogens and reservoirs, we'll go on to learning about seven diseases that insects transmit to humans. These seven diseases are classified into three groups: bacterial, protozoan, and viral. Bacteria are unicellular organisms that lack nuclei. Their DNA is not contained and is just freely floating about in their cytoplasm. Once bacteria invade the host, they often resist immune defenses and begin growing and harm the host in some way. Some bacteria, like rickettsia, invade tissues and cause typhus. Others produce toxins that damage tissues. The figures on the right depict salmonella on a cockroach cuticle.

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Viruses are microscopic infectious agents that replicate themselves only within the cells of living hosts.

Many viruses are pathogenic. The term arbovirus refers to a virus that is transmitted by an arthropod, arthropod borne, like we mentioned before. There are approximately 100 known arthropod viruses. They are mainly isolated from mosquitoes. Examples of viruses are yellow fever, West Nile virus, Eastern equine encephalitis virus, Western equine encephalitis virus, and dengue virus. Protozoa consist of a single cell including a nucleus. The cell contains its own structures needed for life functions. Protozoa are a large and diverse complex group with many shapes and sizes. Protozoa can be parasitic, with a requirement of living within another organism, or they can be free living in moist habitats. Protozoan infections include malaria from mosquitoes and African sleeping sickness acquired by the bite of the tsetse fly in Africa.

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All right, with background knowledge firmly in hand, we'll now discuss seven insect transmitted diseases. They are yellow fever, plague, typhus, dengue fever, trypanosomiasis, encephalitis, and malaria. To learn about these diseases you will need to do a little exploring. Be sure to read your textbook readings and fill out tables 1 and 2 on your study guide. The information contained in this table will be what you are tested on.

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Yellow fever is a virus vectored by mosquitoes. Yellow fever is a tropical disease mostly found in Africa and South America. There are two types of yellow fever, each with different infection cycles. Jungle yellow fever is primarily found in monkeys in tropical rainforests. When humans enter the rain forest to work, they can be bitten by mosquitoes that have fed on infected monkeys. The second type of yellow fever is urban yellow fever, which is found mainly in humans. The Aedes aegypti mosquito has adapted to living around humans in urban settings and breeds in most artificial containers such as pots, discarded tires and other vessels that hold water. In 1905, New Orleans recorded the last epidemic of yellow fever in the United States. This mosquito has changed history, because until an eradication program was instituted in the early 1900s, the construction of the Panama canal could not be completed. Not long after that, a vaccine was developed that is still in use today. Also, quarantine methods for ships, planes, and persons traveling from suspected areas with yellow fever are enforced. Mild forms of the virus cause fever and headache, but the severe form causes rapid heartbeat, back pains, bleeding into the skin, nausea and vomiting with internal hemorrhaging leading to coma and possible death.

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Plague: plague can occur where humans and large populations of rats and fleas coexist. Plague is not spread from person to person, but by the bite of an infected flea. Both male and female fleas can transmit the plague bacterium, Yersinia pestis, through their bites. The flea has a temporary obstruction at the entrance of the stomach and when the flea tries to feed repeatedly, back pressure causes the regurgitation of the blood meal to reenter the bite wound. There are two common forms of plague, bubonic and black. Bubonic plague comes with high fever, chills, delirium, bleeding under the skin, enlarged lymph glands called buboes, and prostration. If the plague involves the lungs, pneumonic plague, the infection can be spread to others through coughs or sneezes. In black plague the hemorrhages are black and result in what's called black death. The mortality rate is 50 to 60% and if it is pneumonic is fatal in 24 hours if not treated. Plague is treated with antibiotics such as streptomycin and tetracycline. Since plague is mainly spread through infected fleas, rodent control is of vital importance in infected areas.

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There are two types of typhus: louse borne typhus, known as epidemic typhus, and murine typhus, which is flea borne typhus. Louse borne typhus is transmitted by the human body louse, Pediculus humanus humanus, which houses the infective pathogen Rickettsia prowazekii. Typhus is mostly found in Europe, Africa, Asia, Mexico and South America. The louse acquires the infective pathogen by taking a blood meal from an infected person. The pathogen multiplies fast in the midgut of the louse and soon the midgut ruptures and rickettsiae move through the louse's digestive tract. Rickettsiae are then excreted in the louse's fecal material and can remain alive for more than 60 days. Host infection is through fecal contamination, not by the actual bite. Scratching a bite often smears the fecal pellet into the bite wound and causes the infection. The rickettsiae are pathogenic to the louse and the louse dies within eight to

twelve days. If the louse does survive infection, it remains infective for life. Epidemic typhus, the most serious of the two, is characterized by high fever with a rash and headache. Antibiotics like tetracycline and chloramphenicol do work on rickettsiae, although the pathogens are not exactly a bacteria. There is a typhus vaccination available and outbreaks usually occur during crowded, unsanitary conditions and has been a major killer in wartime. Murine typhus is transmitted by fleas and is a much milder disease.

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Dengue fever is caused by the DEN virus and is primarily found in warm tropical areas. Dengue is vectored by six species of mosquitoes in the genus Aedes, especially Aedes aegypti. These mosquitoes are distributed worldwide, and the first reported epidemics in 1779 and 1780 appeared in Asia, Africa and North America. Currently DEN viruses are found in Southeast Asia, the Caribbean basin, Mexico, the South Pacific, Central and South America. Dengue was considered to be a nonfatal disease until four distinct virus serotypes, DEN-1 through DEN-4, were discovered. The mild form of dengue is known as breakbone fever because, besides a rash, fever and severe headaches, there is an intense muscle and joint pain. Most people infected with this form make a complete recovery. However, severe cases known as dengue hemorrhagic fever and dengue shock syndrome can occur if the infected person is exposed to one serotype followed by exposure to another serotype within approximately 5 years. Most fatal cases are among children and young adults, with most countries reporting about a 5% fatality rate. People infected with dengue need to rest and drink plenty of water because there is no specific treatment. Dengue hemorrhagic fever requires replacement of lost fluids, and most people require transfusions to control the blood loss.

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Trypanosomiasis, protozoan African sleeping sickness: Glossina species of the order diptera are the chief vectors of the pathogen Trypanosoma brucei gambiense and Trypanosoma brucei rhodensiense that causes African sleeping sickness. The reservoir for the Gambian strain is human and often is referred to as the chronic form and is distinctly a human disease. The concentration of trypanosomes in blood is usually low, thus requiring constant contact between the tsetse fly and man. The low parasitemia helps with building antigens against the parasite and causes the Gambian strain to be the mildest form. The reservoirs for the Rhodesian strain are humans and antelopes.

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Protozoan Chagas disease: conenose bugs belonging to the order Hemiptera and the genus Triatoma are the chief vectors of Chagas disease. The pathogenic organism transferred is a flagellate protozoan known as Trypanosoma. Reservoirs are man, mammals, armadillos, rodents, carnivores, and monkeys. The Trypanosoma is associated with the bite of the vector. Other avenues of infection include the vector dropping its feces on a sleeping person as it is taking a blood meal. The disease runs its course rapidly, and usually within four weeks of the infection, if the patient recovers, the disease enters the chronic stage where the parasite and the host set up an equilibrium. In chronic cases, death can occur suddenly because the trypanosome sets up residence in the heart and destroys cardiac, as well as other, body cells.

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Encephalitis: there are five viruses vectored by mosquitoes that infect horses and humans: Eastern equine encephalitis, Western equine encephalitis, Venezuelan equine encephalitis, St. Louis equine encephalitis, and West Nile virus. Mosquitoes feed on wild birds infected with the virus, then transfer the virus to horses and humans. The symptoms for different encephalitis include fever, drowsiness, and depending on type, paralysis leading to death. The Eastern type is the most virulent, with a 90% mortality rate happening in two to three days. The Western type has about a 50% mortality. Annual vaccination of horses is needed to prevent the disease from spreading because no specific treatment is known. West Nile virus is related to a number of viruses that cause encephalitis. Mosquitoes vectoring this virus can infect approximately 200 animal species, including horses, alligators and many common birds. Approximately 1/5 of the infections taking place in humans develops into West Nile fever. Generally less than 1% of persons that develop a severe case of West Nile fever transition into a severe case of encephalitis or meningitis. The first recorded incidence of West Nile virus was in Queens, New York, in 1999. Since then with the high distribution of migrating birds, West Nile virus has been found in

most of the United States and areas surrounding North America.

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And finally, malaria. There are four species of Plasmodium that cause human malaria: Plasmodium falciparum, Plasmodium malariae, Plasmodium vivax and Plasmodium ovale. Plasmodium falciparum is the most severe and often fatal. During World War II in some parts of Asia, this strain of malaria claimed the lives of more military personnel than enemy fire. The anopheline mosquito is responsible for the transmission of human malaria. The adult mosquito takes a blood meal containing the sexual stages, the microgamete male and macrogamete female, from an infected host. These stages fertilize in the gut of the mosquito and bore through the gut wall making an oocyte. The oocyte develops into an infective stage called a sporozoyte. The oocyte ruptures, and the infective sporozoytes travel up to the salivary glands of the mosquito and are injected into the next host during the next blood meal. When malaria begins, there is a cycle of fever and chills that last several hours and reoccur every three to four days. If untreated, the spleen and the liver become enlarged, anemia develops, and jaundice appears. Death may occur, especially in infants, elderly, and pregnant women. That was a lot of information to cover and hopefully you gleaned a lot of information from your textbook readings or any of the online sources listed. Take a few minutes now and take the quiz to test your knowledge of medical entomology.

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Disease Quiz

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Now that you’re an expert on insect transmitted diseases, read the following case studies and try to diagnose which insect transmitted disease would go along with each case. Good luck.

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(No audio)

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(No audio)

[35]
Review Quiz

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How did you do on the case studies? Were you able to tell from the points which disease and what types of treatment each one had? If you have any trouble with the case studies, be sure to go back and read them. Take note of all of the points and see if you can come up with a treatment strategy for each disease. Before we get to the conclusion, the answers from a case studies were: number one, Dengue fever, number two, malaria, and number three was a Rickettsial bacterial infection. All right, be sure to review all of the lesson objectives. See if you can give an example of each of these: a mechanical reaction, exsanguinations, myiasis, a toxin or paralysis, an allergic reaction, entomophobia, and an arbovirus. These are all part of your lesson objectives, so make sure you review all of them before going on. This concludes unit 15 and this course. Remember to review all of your notes for the final exam and turn in all of your journal entries. I hope you've enjoyed Principles of Entomology.