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Ratio', a cytoplasmically inherited agent that causes female wasps to produce nearly 100% daughters.

Male killing in Coccinellidae

The Coccinellidae appear particularly prone to invasion by male-killing organisms, with four different groups (*Rickettsia*, *Spiroplasma*, Flavobacteria and *Wolbachia*) having been associated with this phenomenon. Coccinellids may be especially susceptible to invasion by male-killing microbes due to their behavior; coccinellids typically feed on aphid populations that are patchy and deposit eggs in tight batches. This behavior could promote egg cannibalism by newly hatched larvae when normal prey populations are low. Such cannibalism could provide an additional mechanism by which the bacteria are transmitted to new individuals.

The evolution of the male-killing ability may have evolved in the bacteria because they are almost exclusively transmitted vertically from mother to eggs; thus, bacteria in male hosts are an evolutionary dead end, so male-killing has a fitness cost of zero from the bacterial point of view. Furthermore, the death of male embryos could augment the fitness of the remaining female brood members by providing food to those females carrying the relatives of the male-killing bacteria. A full understanding of the evolutionary dynamics of male-killers and their hosts remains elusive.

See also, REPRODUCTION.

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Relevant website

The European *Wolbachia* Project: Towards Novel Biotechnological Approaches for Control of Arthropod Pests and Modification of Beneficial Arthropod Species by Endosymbiotic Bacteria. http://wit.integratedgenomics.com/GOLD/Wolbachia.html

http://www.ncbi.nim.nih.gov

SEXUAL RECOMBINATION. The process by which DNA is exchanged by homologous chromosomes by pairing and crossing over during meiosis.

SEXUAL REPRODUCTION. Reproduction involving the union of gametes. (contrast with parthenogenetic reproduction)

SEXUALES. In aphids, the sexual forms of male and females.

SEXUAL SELECTION. Sexual selection is the class (i.e., form, section, axis) of natural selection that is associated with genetic differences among individuals in their ability to (a) compete for, or (b) select, fertile partners in reproduction (i.e., mates). The former is typically associated with males, and the latter, with the female sexual role, but such distinction is continually eroded as ever more is learned of the details of mating behavior in different kinds of organisms.

Competition and mate attraction on the one hand, and mate choice on the other, can involve: direct physical combat among rivals; physical appearance reflecting health (e.g., symmetry or conformity, to "type," as these reflect nutritional and disease history); vigor or strength as demonstrated via "ritualized" displays; the ability to provide or defend resources for partners, and many other comparative and competitive categories and situations.

It can be useful to think of natural selection and sexual selection as the agents of genetic changes that promote individual adaptation (any genetically controlled attribute – e.g., structure, physiological

process, or behavior – that increases an organism's probable genetic contribution to succeeding generations; a characteristic that enhances an organism's chances of perpetuating its genes, usually by leaving descendants) in genetic lineages along two axes: the first axis, ecological/somatic adaptation is that connected with growth, development, maintenance, and survival; and the second, reproductive/genetic adaptation is that directly connected with procreation, the successful production of competitive, fertile offspring. Such a separation in a thought experiment quickly reveals the strong connection yet important distinction that exists between natural and sexual selections, and that must be recognized by entomologists in a number of fields – taxonomy, behavioral ecology, ecology, and pest control and management, to mention a few. For example, a taxonomist who wishes to understand the process of speciation and the genetic divergence of populations needs to give special attention to the mate choice aspects of sexual selection and its connection with classical "reproductive isolation" theory.

Examples of sexual selection phenomena in insects include weapons used by males to control resources and gain access to females. If a resource, something that females lay their eggs into or eat is relatively rare, then males that wait on or near the resource are likely to encounter potential mates among the females that come to oviposit or feed. If this resource is relatively small, then a male may be able to keep it and its associated females to himself by defeating intruding males. Under these circumstances males may have evolved weapons that intimidate or help physically remove sexual rivals. In certain wood and dung-feeding beetles (Scarabaeidae), males sometimes have enormous horns arising from the head and prothorax that are used as levers or pinchers to fling or carry other males from branches, logs, and feces.

Examples of male display and female choice are seen when resources are relatively common, and males cannot profitably wait by an oviposition or feeding site to encounter females. In such situations, should females encounter male interference at a resource site they can easily find another, one without males, where they are not forced to fend off or submit to sexual advances. Under these circumstances males tend to evolve courtship displays that persuade females that they are suitable mates. For example, certain Tephritidae, such as *Ceratitis capitata* Wiedemann (the Mediterranean fruit fly), are among the most serious pests of fruits and limit exports wherever they occur. Males produce a buzzing sound ("song") with their wings as they attempt to mate, and within limits, females select as mates those with louder songs, even when a male's effort is artificially amplified by playing a recorded song at a higher volume than one could otherwise produce. The "meaning" of (i.e., relevant information within) such displays is often difficult to decipher, but it may be that the song is a display of vigor that advertises an underlying genetic quality.

Sex role reversals sometimes occur in species with male "nuptial gifts." Males sometimes provide females with a food item before mating, and in these circumstances females appear to choose mates based on the quality of the gift presented. It may be that females are primarily interested in the food, but they may also judge the ability of the male, i.e., his underlying genetic quality, by his capacity to find and capture or produce certain items. In a number of katydids (Tettigoniidae), including the agricultural pest the Mormon cricket (*Anabrus simplex Haldeman*), males produce a very large spermatophylax. This protein-containing wad of cheese-like material is associated with the ejaculate and can constitute as much as 30% of a male's body weight. Females use this substance as food and those that receive larger "gifts" have greater fecundity (achieved reproduction). When other foods are scarce, and in species where males produce an exceptionally large gift, there sometimes occurs a sex-role reversal. That is, it is the females that seek out and display toward choosy males. Male Mormon crickets estimate the weight of a potential mate, hence the numbers of eggs she is likely to produce in the future as she mounts him (orthoptera fashion) prior to copulation. Males reject light-weight females in favor heavier ones, and in this way promote the favored outcome, that their resources will be used in the production of greater numbers of offspring.

See also, VISUAL MATING SIGNALS.

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SEXUPARA. (pl., sexuparae) In aphids of the family Pemphigidae, winged viviparous parthenogenetic females that produce both males and females. See also, APHIDS.

SHADE TREE ARTHROPODS AND THEIR MANAGEMENT. There are unique issues associated with arthropod management of shade trees. These include: the high value of the plant material, including replacement costs; the siting of plants in areas of high human traffic; the unique management considerations associated with the above; and the aesthetic issues that can be important in management decisions.

Almost invariably, shade trees are a blend of native species and, increasingly, exotic species that have desirable features for the site. Concurrently, associated arthropod pests are also a mixture of native and exotic species and in many areas, the latter predominate. For example, among the more serious exotic shade tree pest species present in the United States are the gypsy moth, *Lymantria dispar* (L.), oystershell scale, *Lepidosaphes ulmi* (L.), the European elm bark beetle, *Scolytus multistriatus* (Marsham), the twospotted spider mite, *Tetranychus urticae* (Koch), and the Japanese beetle, *Popillia japonica* (Newman).

Hundreds of species of insects and mites seriously affect shade trees worldwide. These are often differentiated using a combination of taxa and feeding habits.

ARTHROPODS WITH SUCKING MOUTHPARTS.

Aphids. These may be considered in a broad sense to include 'true aphids' (Aphididae), as well as 'woolly aphids' associated with deciduous plants (Aphididae: Eriosomatinae) and adelgids (Adelgidae). Aphids primarily extract sap from the phloem. This injury is often well tolerated by healthy plants, but may be a serious stress. Species that colonize branches and trunks, such as the hemlock woolly adelgid (*Adelges tsugae* Annand), can be particularly damaging. On some plants, aphids colonize during periods of new growth and produce serious curling distortions of leaves or needles that can adversely affect the growth and form of plants. Aphids (Aphididae) also excrete honeydew, a significant aesthetic problem with shade trees. Among the more important aphids associated with North American shade trees are the tuliptree aphid, *Illinoia liriodendri* (Monell), the apple aphid, *Aphis pomi* De Geer, the giant willow aphid, *Tuberolachnus salignus* (Gmelin), the Norway maple aphid, *Periphyllus lyropictus* (Kessler), the leafcurl ash aphid, *Prociphilus fraxinifolii* (Riley), and the woolly apple aphid, *Eriosoma lanigerum* (Hausmann).

Soft scales. Several families of scales within the superfamily Coccoidea are associated with shade trees. Most share habits that include: phloem feeding with associated honeydew production; mobility after the first instar (crawler stage), often involving migration with early instars on foliage and later stages on small branches and twigs; and the production of hundreds or even a couple thousand eggs. Damage can include loss of vigor, dieback of branches and nuisance problems associated with honeydew.

The most important family is Coccidae, the soft scales. Among the more damaging species in North America are the cottony maple scale, *Pulvinaria innumerabilis* (Rathvon), the striped pine scale, *Toumeyella pini* (King), the European fruit lecanium, *Parthenolecanium corni* (Bouché) and the calico scale, *Eulecanium cerasorum* (Cockerell). Related families of scales of importance to shade trees include giant scales or the margarodids (Margarodidae), gall-like scales (Kermesidae), eriococcids