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Importance of Cynipidae Family (Hymenoptera) ornamental and food plants

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Abstract

Reproduction of gall wasps is partially by sexual reproduction and partially by parthenogenesis, where the male is completely unnecessary. As in many species, however, there is an alternation of generations with one to two sexual generations and one parthenogenetic generation annually. This process differentiates the various generations in their appearance and in the way they induce the galls. The larvae of many species develop gallant characteristics; and there are also many species that are tenants or parasites of other gall wasps, such as those of the genus *Synergus.* This mini review aims to verify the importance of Cynipidae Family ornamental and food plants. To this end, a bibliographic survey of Cynipidae was carried out in the years 1937 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic and Science.

Keywords: Galls; Hyperparasitoid; Larvae; Parthenogenic; Damage

1. Introduction

Cynipidae is a family of hymenopteran insects of the Apocrita subborder, superfamily Cynipoidea, commonly known as gall wasps. Its common name comes from the galls that induce the plants with a view to complete or larval development (Figures 1 and 2) [1].

(Source: https://entomologytoday.org/cynipidae-wasps-large/)

Figure 1 Specimens of Cynipidae

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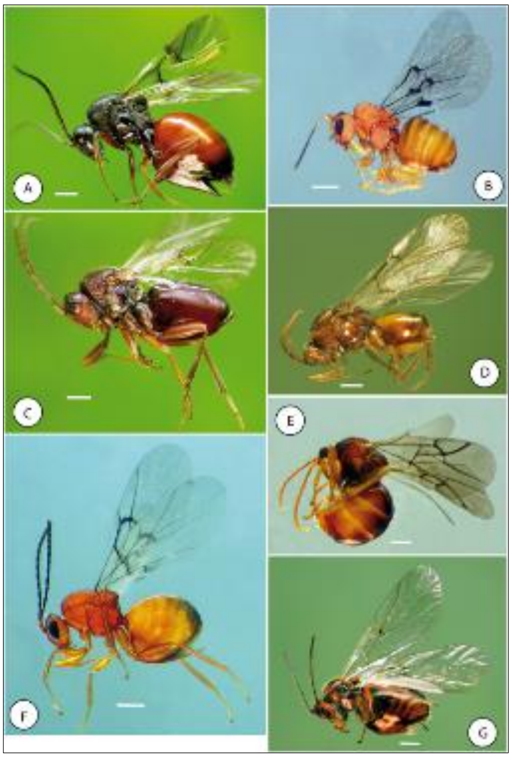
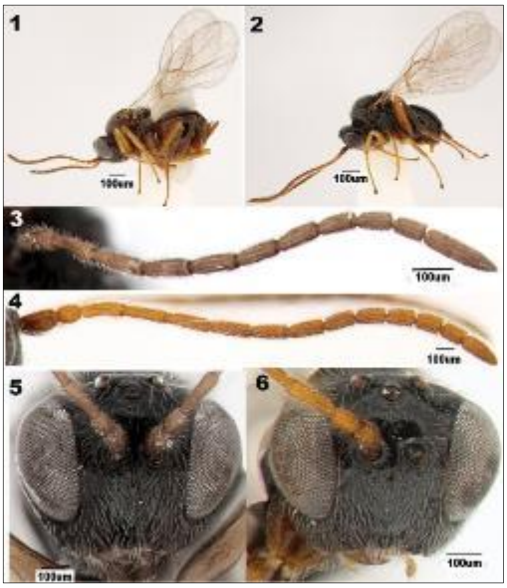


(Source: https://www.researchgate.net/figure/Habitus-of-exemplar-species-of-tribes-of-Cynipidae-A-Diplolepis-mayri-Schlechtendal_fig15_277084341)

Figure 2 Habitus of exemplary species of tribes of Cynipidae. A) *Diplolepis mayri* (Schlechtendal, 1877) (Diplolepidini). B) *Eschatocerus acaciae* Mayr, 1881 (Eschatocerini). C) *Synergus umbraculus* (Olivier, 1791), (Synergini sensu stricto). D) *Pediaspis aceris* (Gmelin, 1790) (Pediaspidini). E) *Qwaqwaia scolopiae* (Qwaqwaiini) iljeblad, Nieves-Aldrey & Melika, 2011. F) *Plagiotrochus australis* (Mayr, 1882). (Cynipini) and G) *Cynips disticha* Hartig, 1840. (Cynipini). Scale bar 0.5 mm

1.1 Characteristics

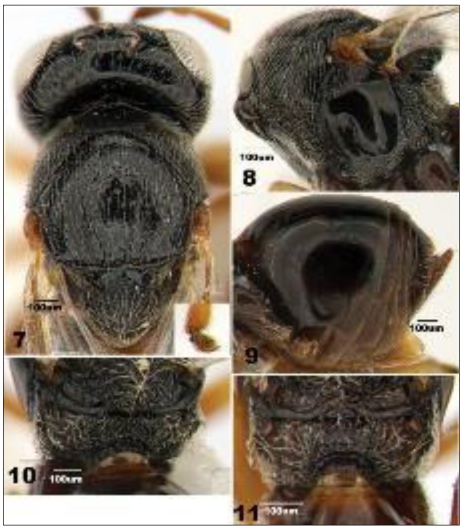


(Source: https://zookeys.pensoft.net/article/47441/)

Figure 3 1 general habitus (♀) 2 general habitus (♂) 3 antenna (♀) 4 antenna (♂) 5 head in anterior view (♀) 6 head in anterior view (♂)

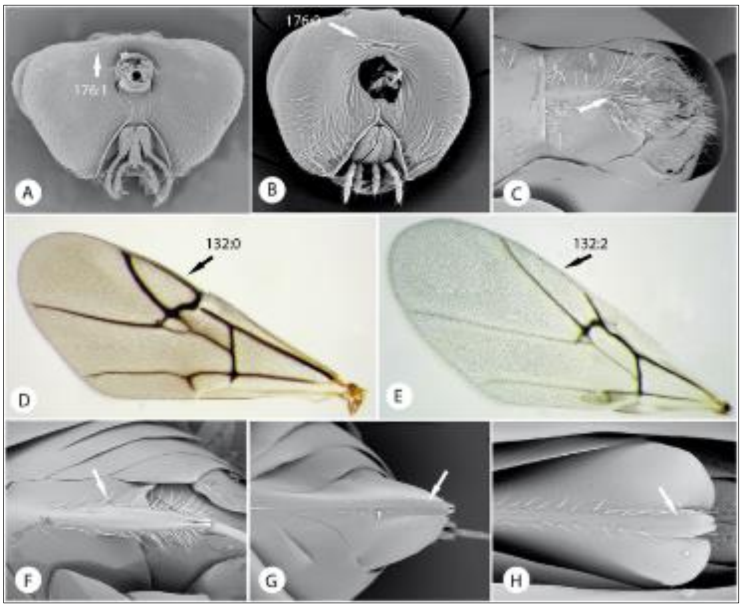
Like all Apocrita representatives, gall wasps have a distinctive body shape, the so-called wasp waist (thin connection between the thorax and abdomen). The first abdominal segment (tergite) called the propodeum is united with the thorax, while the second abdominal segment forms a kind of splinter, the petiole, which connects with the rest of the abdomen (gaster); the latter is the functional abdomen in apocrite wasps, starting with the third abdominal segment itself [1,2,3].

Together, the petiole and gaster form the metasoma, while the thorax and propodeum form the mesosoma. The antennae are straight and consist of 12 to 16 segments. In many varieties the dorsal part of the mesosoma shows longitudinal bands. The wings are typically single-veined. The ovipositor of the female, which serves to deposit the eggs, usually protrudes beyond the metasoma (Figures 4, 5, 6, 7 and 8) [4,5,6].



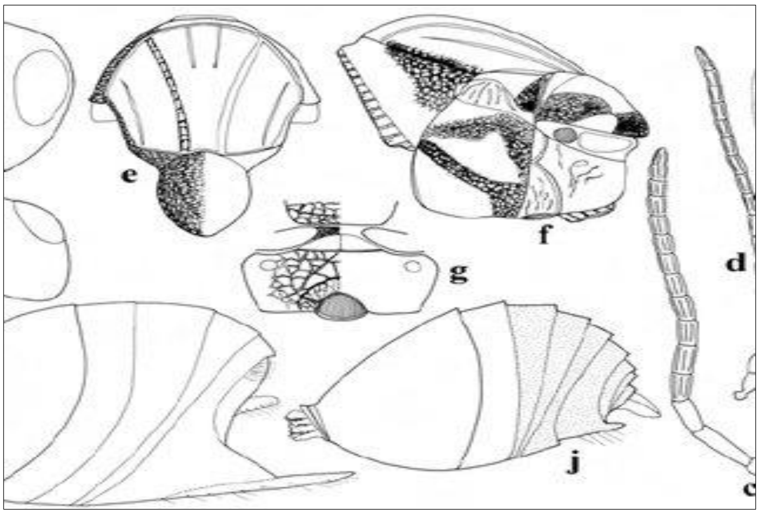
(Source: https://zookeys.pensoft.net/article/47441/)

Figure 4 7 head and mesoma in dorsal view (♀, similar in ♂) 8 mesoma in lateral view (♀) 9 metasoma in lateral view (♀) 10 propodeum in dorsal view (♀) 11 propodeum in dorsal view (♂)



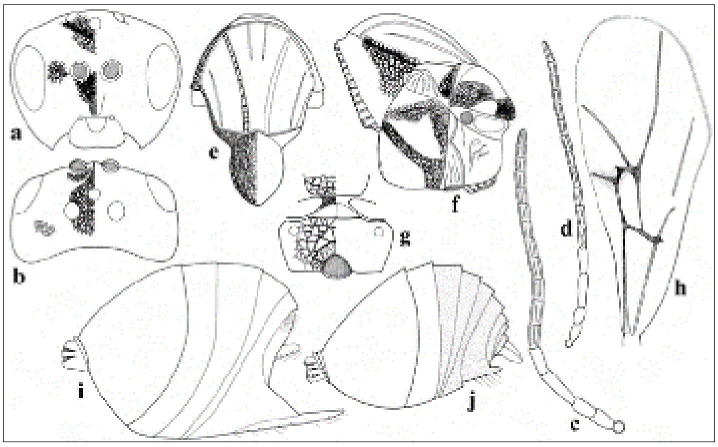
(Source: https://zookeys.pensoft.net/article/47441/)

Figure 5 Morphological characters of tribes of Cynipidae. A) *Qwaqwaia scolopiae* Liljeblad Nieves-Aldrey & Melika, 2011, head in posterior view. B) *Xestophanes potentillae* (Retzius in De Geer, 1773), head in posterior view. C) hypopygium in ventral view and D) fore wing of *Q. scolopiae*. E) fore wing of *Plagiotrochus razeti* Barbotin, 2006. F) *Amphibolips castroviejoi* Nives-Aldrey & Medianero, 1953, hypopygium in ventral view. G) *Aulacidea hieracii* (L., 1758), hypopygium. H) *Synergus ibericus* Tavares, 1920, hypopygium



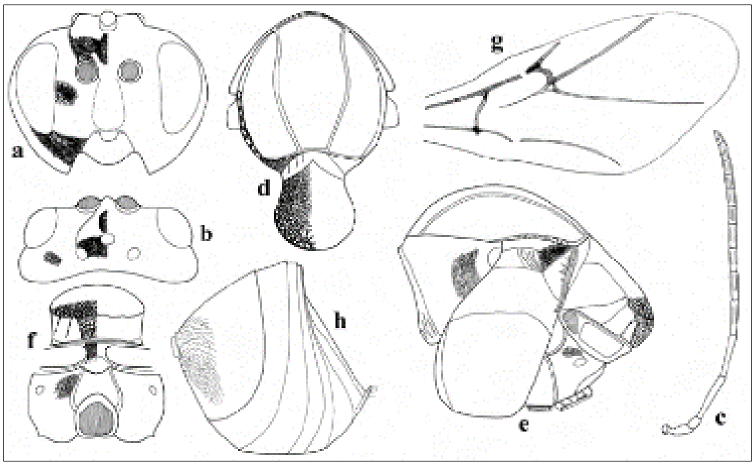
(Source: file:///C:/Users/User/Downloads/AbeetalEastpalreviewsm.pdf)

Figure 6 Female: a-b, head: a, front view, b, from above, c, antenna: d, pronotum, dorsal view, e, scutum and scutellum, dorsal view, f, mesosoma, lateral view, g, propodeum and dorsellum, dorso-posterior view, h, forewing, part, i, metasoma, lateral view



(Source: https://www.researchgate.net/figure/Liebelia-dzhungarica-a-b-head-female-a-front-view-b-from-above-c-d-antenna-c_fig2_233253693)

Figure 7 Head, female: a, front view, b, from above. c-d, antenna: c, female, d, male. e-h, female: e, scutum and scutellum, dorsal view, f, mesosoma, lateral view, g, propodeum and dorsellum, dorso-posterior view, h, forewing. i-j, metasoma, lateral view: i, female, j, male



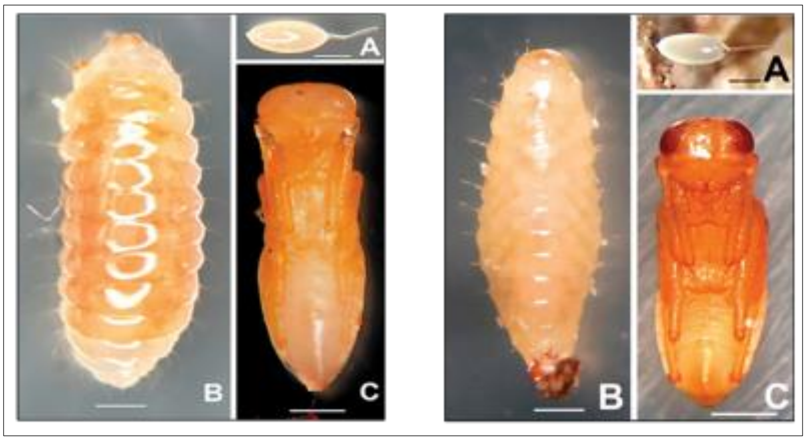
(Source: https://www.researchgate.net/figure/Liebelia-dzhungarica-a-b-head-female-a-front-view-b-from-above-c-d-antenna-c_fig2_233253693)

Figure 8 Female: a-b, head: a, front view, b, from above. c antenna, d, scutum and scutellum, dorsal view, and mesosoma, lateral view, f, propodeum and dorsellum, dorso-posterior view, g, forewing, h, metasoma, lateral view

1.2 Reproduction and development

Reproduction of gall wasps is partially by sexual reproduction and partially by parthenogenesis, where the male is completely unnecessary. As in many species, however, there is an alternation of generations with one to two sexual generations and one parthenogenetic generation annually. This process differentiates the various generations in their appearance and in the way they induce the galls [7,8,9].

The larvae of many species develop gallant characteristics; and there are also many species that are tenants or parasites of other gall wasps, such as those of the genus *Synergus* (Figure 9) ([7,8,9].



(Source: https://jhr.pensoft.net/article/68556/)

Figure 9 Immature stages of E. messene A egg B final-instar larva C female pupa. Scale bars: 0.1 mm (A); 0.3 mm (B); 0.5 mm (C), Figure 9B Egg B final-instar larva C male pupa. Scale bars: 0.1 mm (A); 0.4 mm (B); 0.5 mm (C);

Coots mostly develop directly after the female oviposits. The induction for the formation of galleries is largely unknown. It is not well known what are the triggering mechanisms, whether chemical, mechanical or viral. The larvae grow by absorbing the nutritive tissues of the gills, where they are also well protected from adverse external environmental effects (Figures 10 and 11) [10,11].

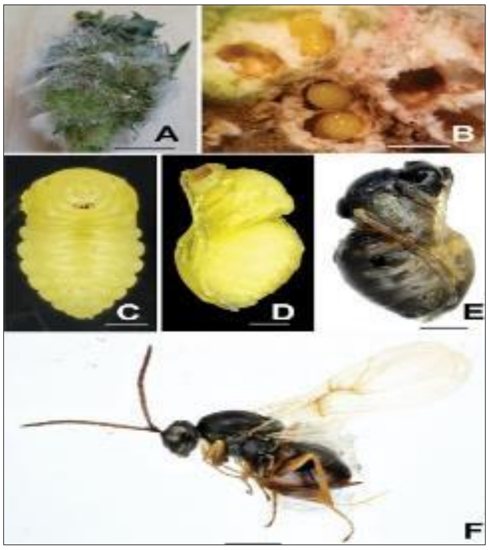
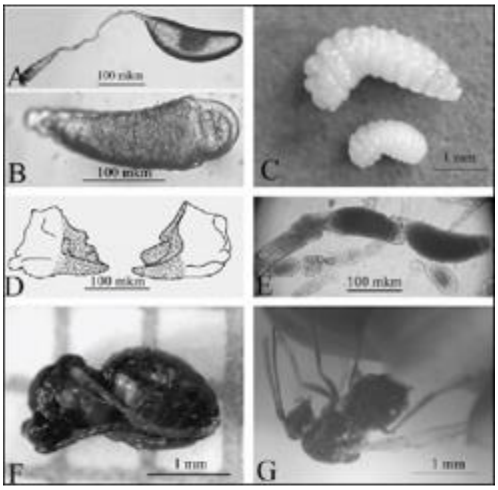


Figure 10 A general view B cross section with mature larvae C late-instar larva D early pupa E late pupa F adult female. Scale bars: 10 mm (A); 2 mm (B); 0.5 mm (C–E); 1.5 mm (F)



(Source: https://www.researchgate.net/figure/Life-cycle-stages-of-Aylax-hypecoi-A-egg-B-newly-hatched-larva-C-last-instar_fig1_226947229)

Figure 11 A) egg; B) newly hatched larva; C) last-instar larvae, upper-female larva, lower-male larva; D) mandible of the larva; E) ovaries with growing eggs; F) pupa; G) female in a moment of oviposition

The host plants and the size and shape of the coots are specific to each wasp species, with 70% of the known species living on various types of oaks. One can find galls on many parts of such trees, some on leaves, stems, branches, roots. Other species of wasps parasitize rose bushes or maples, as well as many grasses. Species determination is often very simple by looking at the galls produced rather than the insect itself [12,13].

1.3 Types

Many species of gall wasps live as gall formers on oak trees. One of the best known of these oak gall wasps is *Cynips quercusfolii* (L., 1758), which induces characteristic spherical galls, 2 cm in diameter, on the underside of oak leaves. They turn reddish in the summer, commonly known as oak apples (Figure 12) [14].

(Source: https://antropocene.it/en/2020/07/01/cynips-quercusfolii/)

Figure 12 Oak or oak apple on oak leaves. insect galls *Cynips quercusfolii* (L., 1758) oak blight in Italy

The galls of the rose wasp *Diplolepis rosae* (Linnaeus, 1758) are distinguished and known as bedeguars. They are found at the foot of the rosebush and are 5 cm long with long red hairs. Inside its gills there are several chambers, occupied by the larvae. Cinipids infest plants in the rose, willow, asters and oak families (Figure 13) [15].

(Source: https://www.dreamstime.com/stock-illustration-cynips-quercusfolii-galls-oak-quercus-scientific-illustration-own-work-image77249531)

Figure 13 *Cynips quercusfolii* (L., 1758) galls on oak *Quercus* Scientific illustration (own work)

Cinipid galls vary greatly in size, shape, and appearance, depending on the host plant and the gall wasp species involved. Gall wasps are not the only organisms that trigger the development of galls on plants, but they are probably the most prolific gall breeders, especially on oaks. About 80% of gall wasps specifically target oaks (Figures 14 and 15) [15].

(Source: https://hedgerowmobile.com/diplolepisrosa.html)

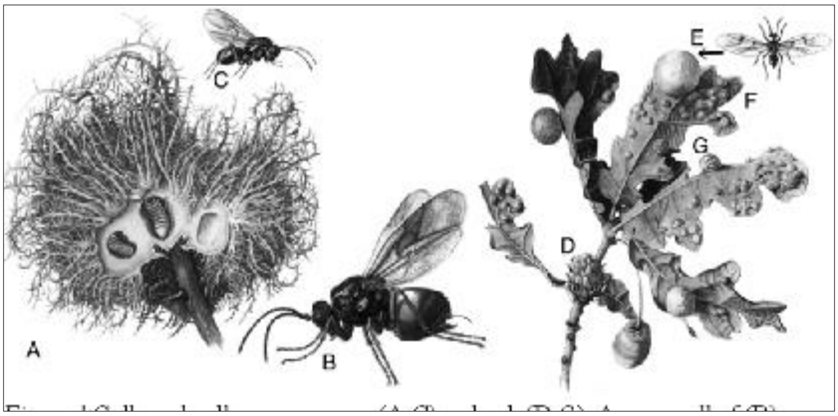
Figure 14 *Diplolepis rosae* (Linnaeus, 1758)

(Source: https://www.biodiversity.no/Pages/225930/)

Figure 15 *Diplolepis rosae* (Linnaeus, 1758) (galls)

1.4 Biology and Ecology

Each tiny white larva lives in its own chamber, constantly feeding. They have no legs and have mouthparts to chew on. Bile wasp larvae obtain nutrition from the galls in which they live. Adult gall wasps are short-lived and do not feed (Figure 16).



(Source: Drawings from Caspari and Grossman (Kronen Verlag)

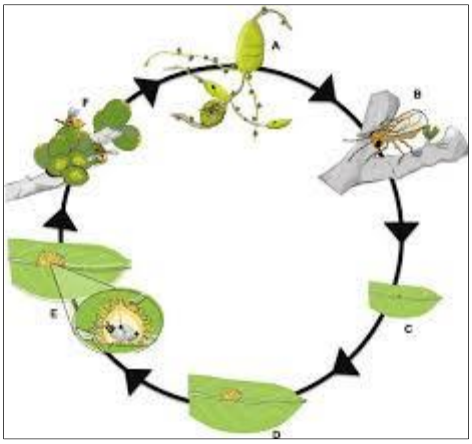
Figure 16 Galls and gall wasps on rose (A-C) and oak (D-G). A- rose gall of (B) *Diplolepis rosae* (Linnaeus, 1758), C- rose gall inquiline *Periclistus brandtii* (Ratzeburg, 1831), D-gall of parthenogentic generation of *Andricus foecundatrix* (Hartig 1840), E-gall and adult gall wasp of parthenogentic generation of *Cynips quercusfolii* Linnaeus, 1758, F-galls of parthenogentic generation of *Neuroterus quercusbaccarum* (Linnaeus, 1758), G-galls of parthenogentic generation of *Cynips longiventris* Hartig, 1840

Surprisingly, for an insect that eats so much, the larvae don't poop. Gall wasp larvae do not have an anus, so there is simply no way to expel their waste. They wait until the pupal stage to rid their bodies of fecal matter [16,17].

1.5 The life cycle of bile wasps

The cinipid life cycle can be quite complex. In some species, male and female gall wasps' mate and the females lay eggs on the host plant. Some wasps are parthenogenetic and rarely, if ever, produce males. Still others alternate sexual and asexual generations, and these separate generations may use different host plants (Figure 17) [16,17].

In very general terms, the gall wasp life cycle involves complete metamorphosis, with four life stages: egg, larva, pupa, and adult. The female lays an egg in the meristematic tissue of the host plant. When the egg hatches and the larva begin to feed, a reaction occurs in the host plant, causing gall formation. The larva feeds inside the gall and eventually enters the pupal stage. The adult gall wasp usually chews an exit hole to escape bile [18].

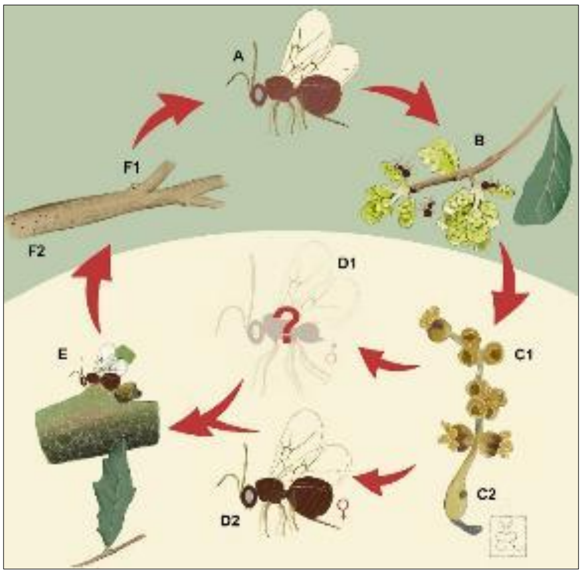


(Source: https://txmn.org/rbc/files/2020/08/Gall-wasps-ref-Hood-et-al-2017-complex-life-cycle-of-a-gall-wasp.pdf)

Figure 17 The life cycle of the cyclically parthenogenic gall wasp, *Andricus quercuslanigera* (Ashmead 1881), on its host plant, *Quercus virginiana* Mill. (Fagaceae), in southeastern Texas. See text in description life History timing and of sexual generation galls section for a detailed description of the life cycle

1.6 Special behaviors of gall wasps

Some wasps do not produce galls on their host plants, but are tenants of the galls of other species. The female wasp lays eggs in an existing gall, and her offspring hatch and feed on it. Inquiline larvae can indirectly kill larvae that have induced bile formation by simply competing with them for food (Figure 18) [19].

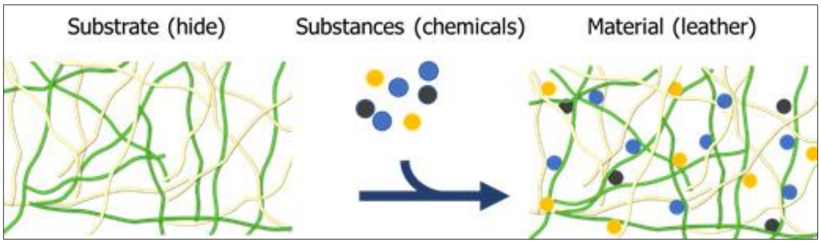


(Source: https://txmn.org/rbc/files/2020/08/Gall-wasps-ref-Hood-et-al-2017-complex-life-cycle-of-a-gall-wasp.pdf)

Figure 18 A cynipid gall wasp that uses chemicals to induce live oak trees to grow protective crypts, or galls, around its eggs. females (A and D2) lay twice per year in alternating generations at different locations on trees. One generation emerges in February or March, laying eggs in live oak flowers (B) and inducing galls (C1) where adults will emerge in 2-3 weeks. These lay eggs at branching stem nodes (E), inducing galls (F1) from which adults will emerge 11 months later? (Male)

1.7 Additional information

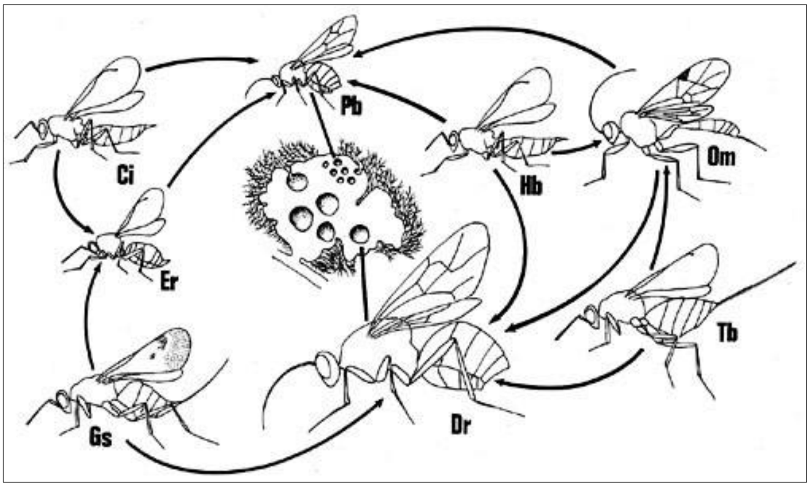
Coot of many species, especially the Mediterranean variants, have already been used as tanning agents. They are used for the production of iron bill ink, widely used in Europe between the 5th and 19th centuries (Figure 19A).



(Source: https://txmn.org/rbc/files/2020/08/Gall-wasps-ref-Hood-et-al-2017-complex-life-cycle-of-a-gall-wasp.pdf)

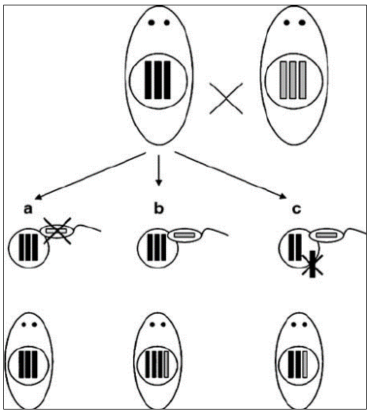
Figure 19A Leather tanning is the process to prepare skins and hides for leather production. Leather tanning is done in a tannery

The gall nut of the rose bush can be used as a durable floral bouquet. Prior to his work on human sexuality, Alfred Kinsey was known for his contributions to the study of gall bladders (Figures 19B and 20) [20].



(Soirce: https://www.nature.com/articles/6883850)

Figure 19B Host-parasitoid relationships among the bedeguar-gall guild. The large cells in the gall are occupied by the gall-maker, Diplolepis rosae (Dr); the small cells by the inquiline, Periclistus brandtii (Pb). Arrows point from parasitoid to host. Further abbreviations: Om, *Orthopelma mediator* (Thunberg, 1822); Hb, *Habrocytus bedeguaris* (Thomson, 1878); Tb, *Torymus bedeguaris* (Linnaeus 1758); Gs, *Glyphomerus stigma* (Fabricius 1793); Er, *Eurytoma rosae* Nees, 1834; Ci, *Caenacis inflexa* (Ratzeburg 1848)



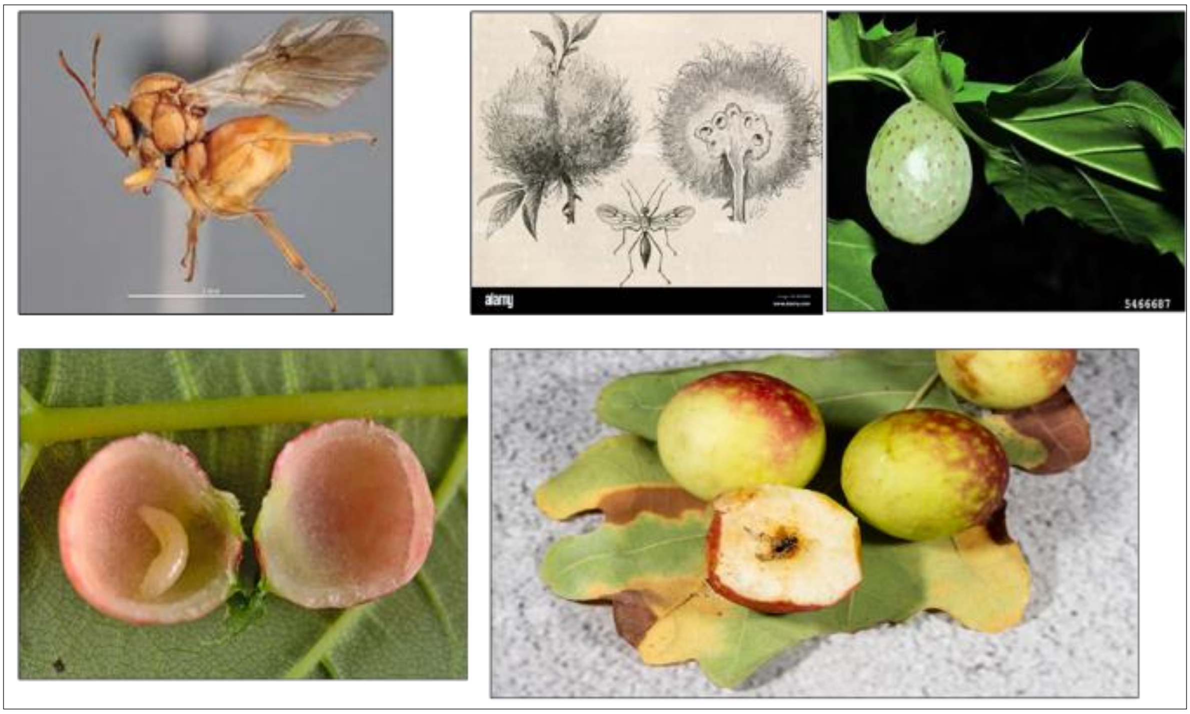
(Source: https://stringfixer.com/pt/Parthenogenesis)

Figure 20 Paternal inheritance in parthenogenetic *Schmidtea polychroa* (Schmidt, 1861) (Cynipidae). Black bars indicate maternal and gray bars paternal chromosome sets. (a) Sperm-dependent parthenogenesis: Haploid sperm is used to trigger embryo development without paternal, genetic contribution to offspring. (b) Chromosome addition:

Haploid sperm fuses with polyploid egg, leading to an increase in ploidy (eg. 3x - 4x). (c) Chromosome displacement: Haploid sperm fuses with polyploid egg and one maternal chromosome set is excluded from the zygote

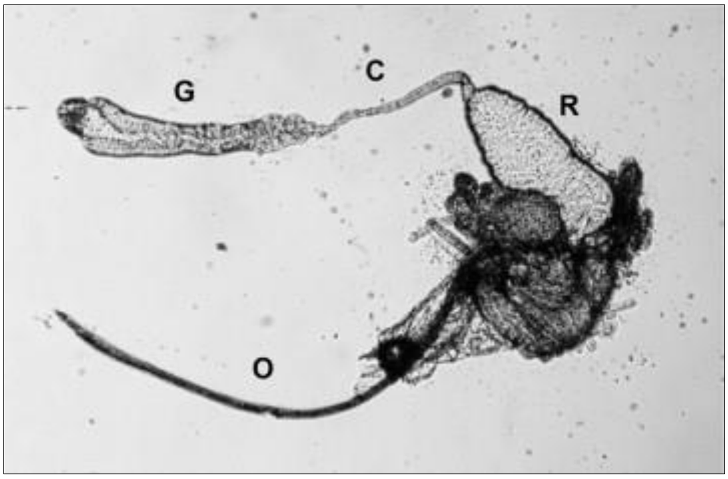
1.8 Taxonomy

The Eucoilinae and Charipinae subfamilies are parasitic, although recent classifications do not place them in this family. In such a case there is a single subfamily Cynipinae, and a fossil subfamily, Hodiernocynipinae† (Figures 21A and 21B) [21,22,23].



(Source: https://www.insectimages.org/browse/taxthumb.cfm?fam=159&genus=Amphibolips)

Figure 21A Subfamily Cynipinae (Oak apples on the underside of an oak leaf. Oak apple, a fly is visible in the section, an insect pest of the nutmeg Cynipinae



(Source: https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/cynipidae)

Figure 21B The venom apparatus is formed by a unique long gland (G) connected to the reservoir © by a canal ©. O, ovipositor. The lumen of the gland, lined by a large epithelium, is visible. The tip or 'nose' region of the gland is half-filled by a darker material. The size of G+C+R is about 1 mm

Ten years of study confirm the presence of 11 genera of gall inducers of the Cynipdae family in the Republic of Panama. The collected data indicate the presence of new genera of inducers that are in the process of being studied for their description [21,22,23].

Objective

This mini review aims to verify the importance of Cynipidae Family ornamental and food plants

2. Material and methods

The method used to prepare this mini review was Marchiori 2021 methodology [14].

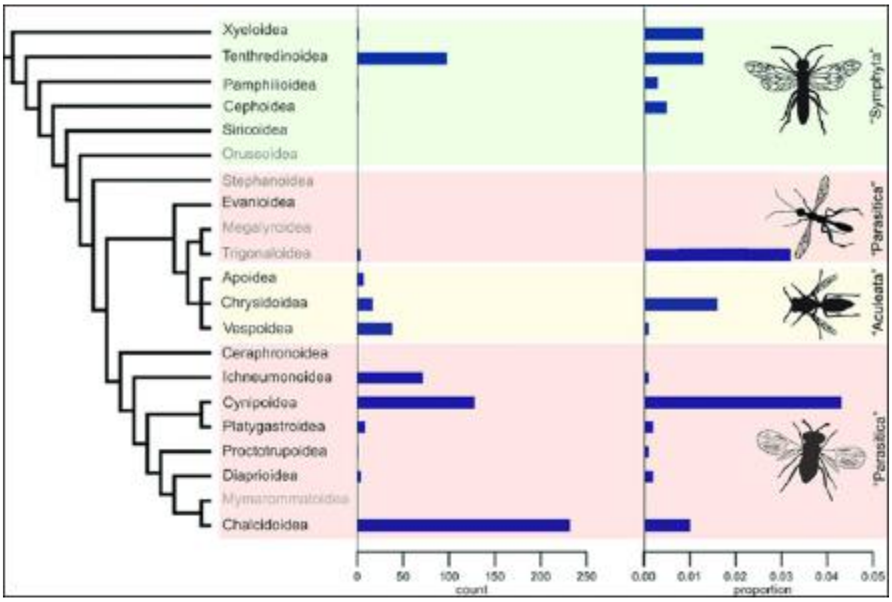
3. Studies conducted and selected

3.1 Study 1

3.1.1 Parthenogenesis

Parthenogenesis is a natural form of asexual reproduction in which the growth and development of embryos occur without fertilization by the sperm. In animals, parthenogenesis means the development of an embryo from an unfertilized egg. In plants, parthenogenesis is a component process of apomixis.

Parthenogenesis occurs naturally in some plants, some species of invertebrate animals (including nematodes, some tardigrades, water fleas, some scorpions, aphids, some mites, some bees, some Phasmatodea, and parasitic wasps), and some vertebrates (Figure 22).

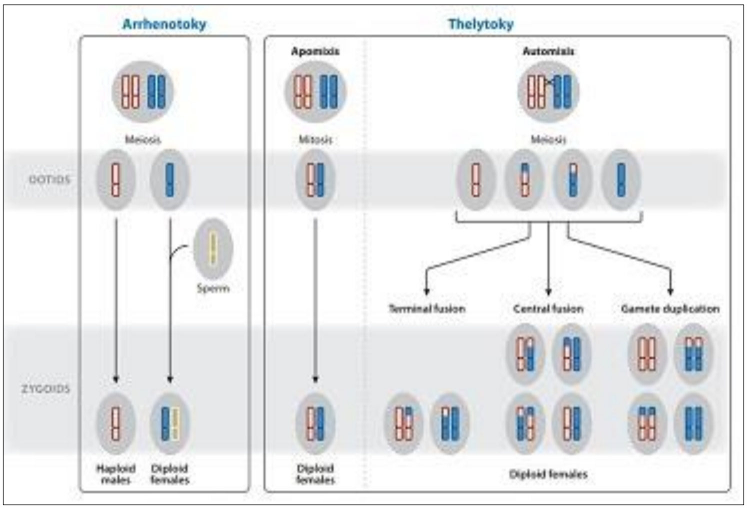


(Source: https://www.researchgate.net/figure/Frequency-of-parthenogenesis-in-Hymenoptera-superfamilies-The-phylogeny-is-from_fig1_320969256)

Figure 22 Frequency of parthenogenesis in Hymenoptera superfamilies. The phylogeny is from Klopfstein et al. (2013); taxa with fewer than 100 species described have gray label names. Except for the Ceraphronoidea, Evanioidea, and Siricoidea, all species-rich taxa have parthenogenetic specie

3.2 Study 1

Normal eggs form after meiosis and are haploid, with half the chromosomes of the mother's body cells. Haploid individuals, however, are generally unviable, and parthenogenetic offspring usually have diploid chromosome numbers (Figure 23).

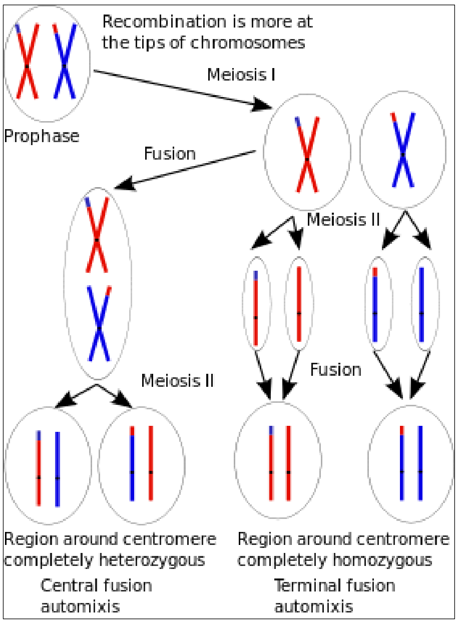


(Source: https://passion-entomologie.fr/parthenogenesis-in-insects-synthesis/)

Figure 23 Deutherotokic parthenogenesis produces unfertilized eggs from both males and females

Depending on the mechanism involved in restoring the diploid number of chromosomes, parthenogenetic offspring may have anything between all and half of the mother's alleles. Offspring with all the genetic material from the mother are called full clones and those with only half are called half-clones. Complete clones are usually formed without meiosis. If meiosis occurs, the offspring will receive only a fraction of the mother's alleles, since DNA crossover occurs during meiosis, creating variation.

Parthenogenetic offspring in species that use the XY or X0 sex determination system have two X chromosomes and are female. In species that use the ZW sex determination system, they have two Z chromosomes (male) or two W chromosomes (most not viable, but rarely a female), or they may have one Z and one W chromosome (Figure 24A).



(Source: https://stringfixer.com/pt/Parthenogenesis)

Figure 24A The effects of central fusion and terminal fusion in heterozygosity

Many taxa with heterogony have within them species that have lost the sexual phase and are now completely asexual. Many other cases of obligate parthenogenesis (or gynogenesis) are found among polyploids and hybrids, where chromosomes cannot pair for meiosis.

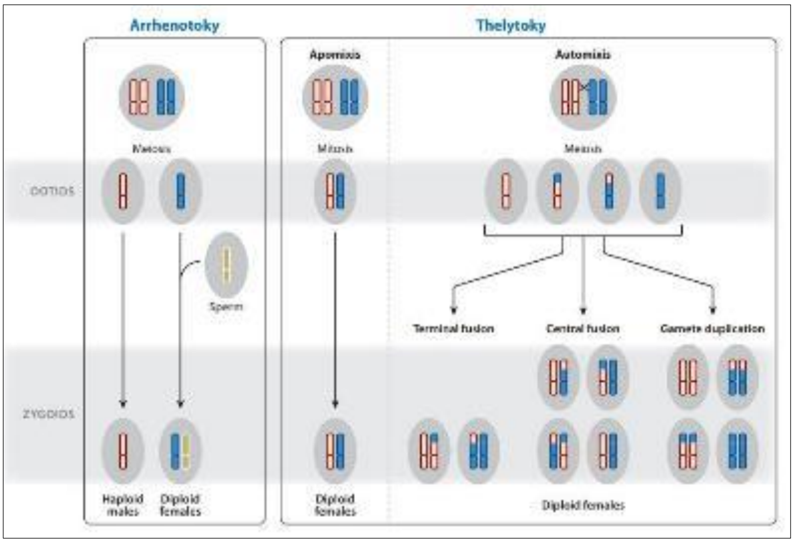
The production of female offspring by parthenogenesis is called thelytoky (eg, aphids), while the production of males by parthenogenesis is called arrhenotocic (eg, bees). When unfertilized eggs develop into males and females, the phenomenon is termed deuterotoky. Parthenogenesis can be optional and obligatory.

3.3 Insects

Parthenogenesis in insects can encompass a wide range of mechanisms. The offspring produced by parthenogenesis can be either sex, only females (thelytoky, e.g. aphids and some hymenoptera or only males (arrenothochia, e.g. most hymenoptera). Both true parthenogenesis and pseudogamy (gynogenesis or sperm-dependent parthenogenesis) are known to occur. Eggs, depending on the species, can be produced without meiosis (apomictically) or by one of several automatic mechanisms.

A related phenomenon, polyembryony is a process that produces multiple clonal offspring from a single egg. This is known in some Hymenoptera parasitoids and in Order Strepsiptera.

In automictic species, the offspring can be haploid or diploid. Diploids are produced by the duplication or fusion of gametes after meiosis. Fusion is seen in Phasmatodea, Hemiptera (Aleurodids and Coccidae), Diptera and some Hymenoptera (Figure 24B).



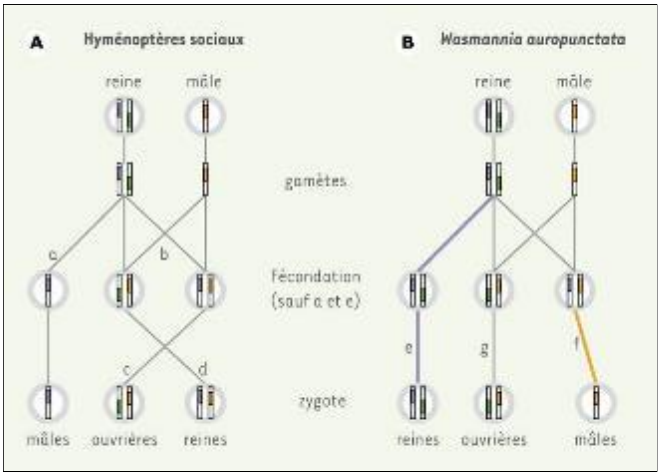
(Source: Rabeling & Kronauer, 2013)

Figure 24B Parthenogenetic thelytoky reproduction modes

In addition to these forms, there is hermaphroditism, in which both eggs and sperm are produced by the same individual, but it is not a type of parthenogenesis. This is seen in three species of *Icerya* scale insects.

Parasitic bacteria such as *Wolbachia* have been noted to induce automitic thelytoky in many insect species with haplodiploid systems. They also cause gametes to duplicate in unfertilized eggs, causing them to develop into female offspring.

Among species with a haplo-diploid sex determination system, such as hymenoptera (ants, bees, and wasps) and thysanopterans (thrips), haploid males are produced from unfertilized eggs. Eggs are normally laid only by the queen, but unmated workers may also lay haploid male eggs regularly (eg, stingless bees) or under special circumstances. An example of non-viable parthenogenesis is common among honeybees. The queen bee is the only fertile female in the hive; if she dies without the possibility of a viable replacement queen, it is not uncommon for workers to lay eggs (Figure 25).



(Source: Rabeling & Kronauer, 2013)

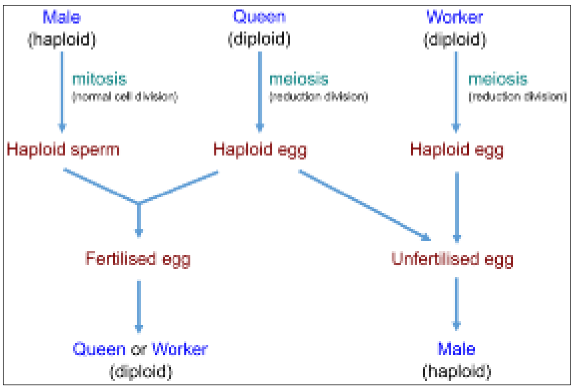
Figure 25 "Classic" reproductive system of social hymenoptera (A) and ant (Wasmannia auropunctata) (Roger 1863) (Hymenoptera: Formicidae: Myrmicinae) (B)

At 30% of parasitoid wasp species (article link) Cynipidae and Chalcidoidea, thelytokia is caused by endosymbiotic microorganisms of the genus *Wolbachia, Cardinium* and *Rickettsia.*

This is a result of the lack of queen pheromones and pheromones secreted by the uncoated brood, which normally suppress ovarian development in workers. Worker bees are unable to mate, and unfertilized eggs produce only drones (males), which can only mate with a queen. Thus, in a relatively short period of time, all the worker bees die, and new drones emerge if they failed to mate before the colony collapsed. This behavior is thought to have evolved to allow a doomed colony to produce drones that can mate with a virgin queen and thus preserve the colony's genetic offspring.

Some ants and bees are capable of producing diploid female offspring parthenogenetically. This includes a South African honeybee subspecies, *Apis mellifera capensis* L., 1758, where workers are able to parthenogenetically produce diploid eggs and replace the queen if she dies; other examples include some species of small carpenter bees, (genus *Ceratina)*. Many parasitic wasps are known to be parthenogenetic, sometimes due to *Wolbachia* infections.

Workers in five ant species and queens in some ants reproduce by parthenogenesis. In the Cataglyphis cursor, European formicin ant, queens and workers can produce new queens by parthenogenesis. Workers are sexually produced (Figure 26).



(Source: https://www.antwiki.org/wiki/Hymenoptera_Sex_Determination)

Figure 26 Haplodiploidy, the production of females (queens, workers) from fertilized eggs and males from unfertilized eggs. See Caste Determination for a discussion of whether queens or workers result from fertilized eggs

In Central and South American electric ants, *Wasmannia auropunctata* (Roger 1863) (Hymenoptera: Formicidae: Myrmicinae), queens produce more queens by automitic parthenogenesis with central fusion. Sterile workers are usually produced from eggs fertilized by males. In some of the eggs fertilized by males, however, fertilization can cause the female genetic material to be removed from the zygote. In this way, males only pass on their genes to become fertile male offspring. This is the first recognized example of an animal species in which females and males can reproduce clonally, resulting in a complete separation of the male and female gene pools. As a consequence, males will have only fathers and queens only mothers, while sterile workers will be the only ones with both fathers of both sexes (Figure 27).

(Source: https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0006781.g004)

Figure 27 Thelytokous parthenogenesis in the fungus-gardening ant *Mycocepurus smithii* (Forel, 1893). (Hymenoptera: Formicidae) **-** Geographic distribution of *Mycocepurus obsoletus* Emery, 1913 (Hymenoptera: Formicidae)

These ants get the benefits of asexual and sexual reproduction the daughters that can reproduce (the queens) have all of the mother's genes, while the sterile workers, whose physical strength and disease resistance are important, are sexually produced [24,25,26,27,28].

3.4 Study 2

3.4.1 Hymenoptera

(Source: http://www.lies.com/wp/2013/08/01/scientificillustration-galls-and-gall-wasps-cynipidae-from/)

Figure 28 Entomogenous galls Cynipidae

Along with the order Diptera, Hymenoptera have the most complex entomogenous galls. The gall-inducing hymenoptera are distributed. in five families (Tenthredinidae, Cynipidae, Agaonidae, Tanaostigmatidae and Eurytomidae) and are found in all biogeographic regions (Figure 28).

There are about 1,000 species of cynipids in 41 genera predominantly found in the Northern Hemisphere. The largest number of known species is in the Nearctic Region, particularly in Mexico, where an estimated 700 species of these wasps in 29 genera.

(Source: http://www.lies.com/wp/2013/08/01/scientificillustration-galls-and-gall-wasps-cynipidae-from/)

Figure 29 Galls and gall wasps *(*Cynipidae)

Cinipids are found on every continent except Australia. In number of species, they are second only to the Cecidomyiidae, but if equal in complexity and variety of morphological types. They induce galls in a wide variety of host plant families, especially Fabaceae, Rosaceae and Aceraceae.

(Source: http://www.lies.com/wp/2013/08/01/scientificillustration-galls-and-gall-wasps-cynipidae-from/)

Figure 30 Formation of a gall by Cynipidae

Regarding their structure, the best studied galls are those induced by Cecidomyiidae and Cynipidae. Morphologically, cinipid galls are characterized by an internal region, formed by nutritive tissues and larvae. of the developing insect; and an external region constituted by an epidermis and a layer of cortical parenchyma (Figure 29).

The inner region is formed by a 'nutritive parenchyma' and by a 'nutritive tissue', which is formed from the parenchyma. The insect larva is in contact with the nutritive tissue that limits the inner wall of the larval chamber. The diversification of the external region is responsible due to the great variability of morphological types of galls. In galls induced by many cinnipids, the inner and outer region it is separated by a thin layer of sclerenchyma. The number of larvae or nymphs per chamber can range from one to hundreds (Figures 30 and 31) [29,30,31,32,33,34].

(Source: http://www.lies.com/wp/2013/08/01/scientificillustration-galls-and-gall-wasps-cynipidae-from/)

Figure 31 The European species *Timaspis cichorii* (Kieffer, 1909) (Hymenoptera Cynipidae), inducing cryptic galls in stems of *Cichorium intybus* L. (Asteraceae), a plant native to the Mediterranean region, is recorded in Chile and on the American continent for the first time. *Phanacis hypochoeridis* (Kieffer, 1887) (Cynipidae), another cynipid introduced from Europe, that forms noticeable galls in the stems of *Hypochoeris glabra* L. (Asteraceae)

3.5 Study 3

A gall provides the developing gall wasp with protection for the most vulnerable stage of its life cycle, but many other wasps have found a way to penetrate this defence and parasitise the larva(e) within. Some of these parasitoids use their long, hardened egg-laying tube (ovipositor) to bore into the gall and lay an egg on the helpless gall maker.

(Source: https://pt.wikipedia.org/wiki/Trigonalidae)

Figure 32 Trigonalidae (Hymenoptera) hyperparasitoids of Cynipidae (Hymenoptera)

A bedeguar or robin's pincushions gall, collected before the autumn and kept cool, may result in at least one species of parasitoid emerging instead of the gall maker. These wasps, such as Eurytoma rosae, are beautiful, metallic insects with long ovipositors. These parasitoids may, in turn, be preyed upon by other wasps, hyperparasitoids. Trigonalidae (Hymenoptera) are therefore parasitoids or hyperparasitoids, but in a unique way within insects, as the egg has to be swallowed by the host. Signiphoridae the species with known Biology are either parasitoids or hyperparasitoids (Figure 33) [35].

(Source: https://bugguide.net/node/view/1358468)

Figure 33 Signiphoridae (Hymenoptera) hyperparasitoids of Cynipidae

3.6 Study 4

3.6.1 Diplolepis rosae (Linnaeus, 1758)

Bedeguar gall, robin's pin cushion, mossyrose gall wasp on *D. r*osae (Figures 34, 35, 36, 37, 38, 39, 40 and 41).

(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

Figure 34 *Diplolepis rosae* (Linnaeus, 1758) usually the galls develop at the end of a branch, and can become quite large then

(Source: © Jean-Yves Baugnée)

Figure 35 *Rosa rubiginosa* L. 1758 (Rosaceae) Belgium, prov. Hainaut Farciennes

(Source: © Hélène Dumas)

Figure 36 *Diplolepis rosae* (Linnaeus, 1758), France, La Ciotat: sometimes the galls develop on other organs, like the leaves; they are much smaller then

(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

Figure 37 *Diplolepis rosae* (Linnaeus, 1758) Lateral view

(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

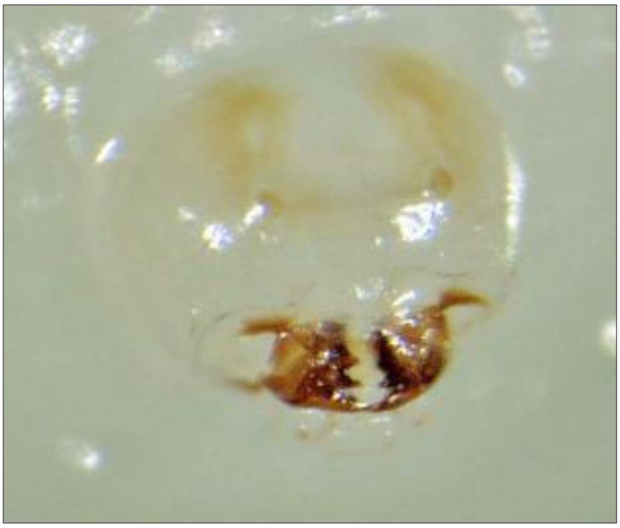
Figure 38 *Diplolepis rosae* (Linnaeus, 1758), Belgium, prov. Namur, Nismes, Fondry des Chiens: detail of the hair cover of the gall

(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

Figure 39 The centre of the gall consists of some tens of chambers, each containing a single larva

(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

Figure 40 *Diplolepis rosae* larva (Cynipidae)



(Source: https://bladmineerders.nl/parasites/animalia/arthropoda/insecta/hymenoptera/apocrita/cynipidae/diplolepis/diplolepis-rosae/)

Figure 41 *Diplolepis rosae* larva mouthparts (Cynipidae)

3.6.2 Host plants

Rosaceae

Rosa agrestis Savi: Arvensis, balsamica, caesia, canina, corymbifera, dumalis, gallica, glauca, inodora, majalis, marginata, micrantha, montana, rubiginosa, sempervirens, sherardii, spinosissima, tomentosa and villosa.

3.6.3 Synonyms

Rhodites rosae L. (Rosacea)

Notes: One of the most conspicuous galls, with real vernacular names like “bedeguar gall” and “robin’s pin cushion”.

3.6.4 Inquilines

Periclistus brandtii (Ratzeburg, 1831) – and many others (Figures 42, 43, 44, 45, 46 and 47) [36,37,38,39,40].

(Source: https://www.dreamstime.com/stock-illustration-dryocosmus-kuriphilus-galls-sweet-chestnut-image77249778)

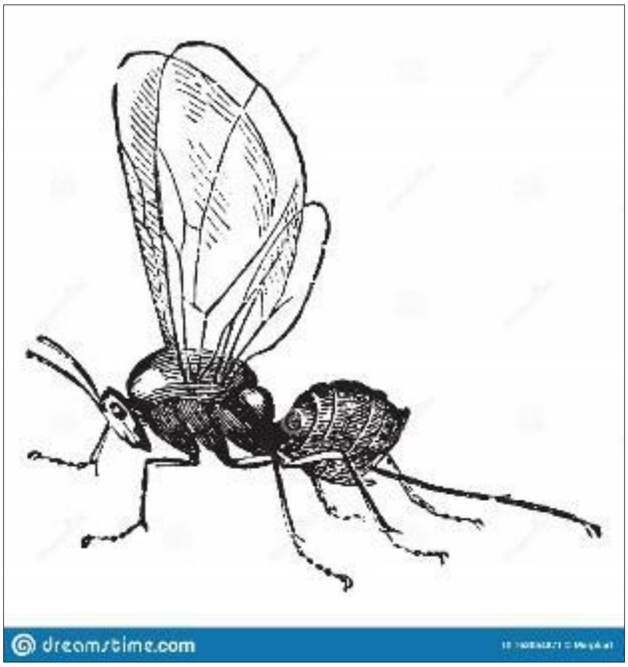
Figure 42 *Dryocosmus kuriphilus* Yasumatsu, 1951 galls on sweet chestnut

(Source: https://www.dreamstime.com/stock-illustration-dryocosmus-kuriphilus-galls-sweet-chestnut-image77249778)

Figure 43 *Dryocosmus kuriphilus* Yasumatsu, 1951 galls on sweet chestnut

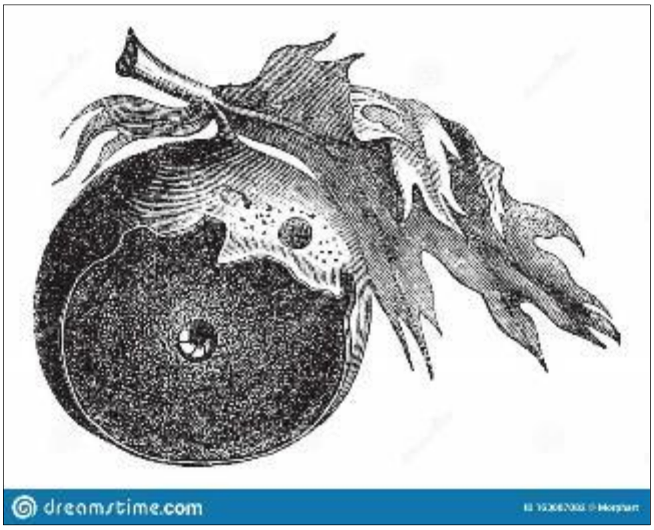
(Source: https://www.dreamstime.com/quercus-lusitanica-gall-oak-vintage-engraving-lusitanian-dyer-s-infectoria-olivier-old-engraved-illustration-plant-galls-image163050980)

Figure 44 *Quercus lusitanica* Lamarck (Fagacea) or gall oak or Lusitanian oak or dyer`s oak or *Quercus infectoria* Olivier (Fagacea), vintage engraving. Old engraved illustration of gall oak, plant and galls isolated on a white background



(Source: https://www.dreamstime.com/quercus-lusitanica-gall-oak-vintage-engraving-lusitanian-dyer-s-infectoria-olivier-old-engraved-illustration-plant-galls-image163050980)

Figure 45 *Quercus lusitanica* Lamarck (Fagacea) or gall oak or Lusitanian oak or dyer`s oak or *Quercus infectoria* Olivier, vintage engraving. Old engraved illustration of gall oak, plant and galls isolated on a white background. (Adult of the Cynipidae Family)



(Source: https://www.dreamstime.com/gall-oak-way-insect-escapes-vintage-engraving-old-engraved-illustration-infectious-worm-its-escape-isolated-image163087082)

Figure 46 Gall of an oak and the way of insect escapes, vintage engraving. Old engraved illustration of gall of an oak with infectious worm and the way of its escape, isolated on a white background

4. Conclusion

Reproduction of gall wasps is partially by sexual reproduction and partially by parthenogenesis, where the male is completely unnecessary. As in many species, however, there is an alternation of generations with one to two sexual generations and one parthenogenetic generation annually. This process differentiates the various generations in their appearance and in the way they induce the galls. The larvae of many species develop gallant characteristics; and there are also many species that are tenants or parasites of other gall wasps, such as those of the genus *Synergus.*

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