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Review Article

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Fossil Insect Life Cycle

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Abstract
The evolution of insect life cycle is an important biological process in animal history. Through multiple adaptation processes, insects became the most diverse and abundant group of animals on Earth. Insect life cycle evolved through different developmental stages from eggs to adults in complete and incomplete metamorphosis. As approached in this study, insect life cycle has been preserved in fossil inclusions providing information about the evolution of these processes.

Keywords: *Amber; Evolution; Fossil; Insect; Metamorphosis.*

1. Introduction: Insect life cycle

Insect life cycles are classified as complete and incomplete with four and three stages developmental processes [1,2]. **Complete metamorphosis** involves development of eggs, larvae, pupas and adults (e.g., butterflies, moths, flies, bees, wasps and beetles). **Incomplete metamorphosis** features eggs, nymphs and adult stages (e.g., cockroaches, termites, dragonflies, true bugs, crickets and grasshoppers). According to Truman and Riddiford (2019) [2], the hypothesis is that insects evolved from an ancestral ametabolous without metamorphosis strategy (e.g., silverfish with eggs, juvenile, adult) to a hemimetabolous ancestor (eggs, nymph, adult) to holometabolous stages in which larvae arose from conversion of an embryonic pronymph stage into the free-living, feeding larva with nymphal stages reduced to a transitional non-feeding stage, the pupa (Fig. 1).

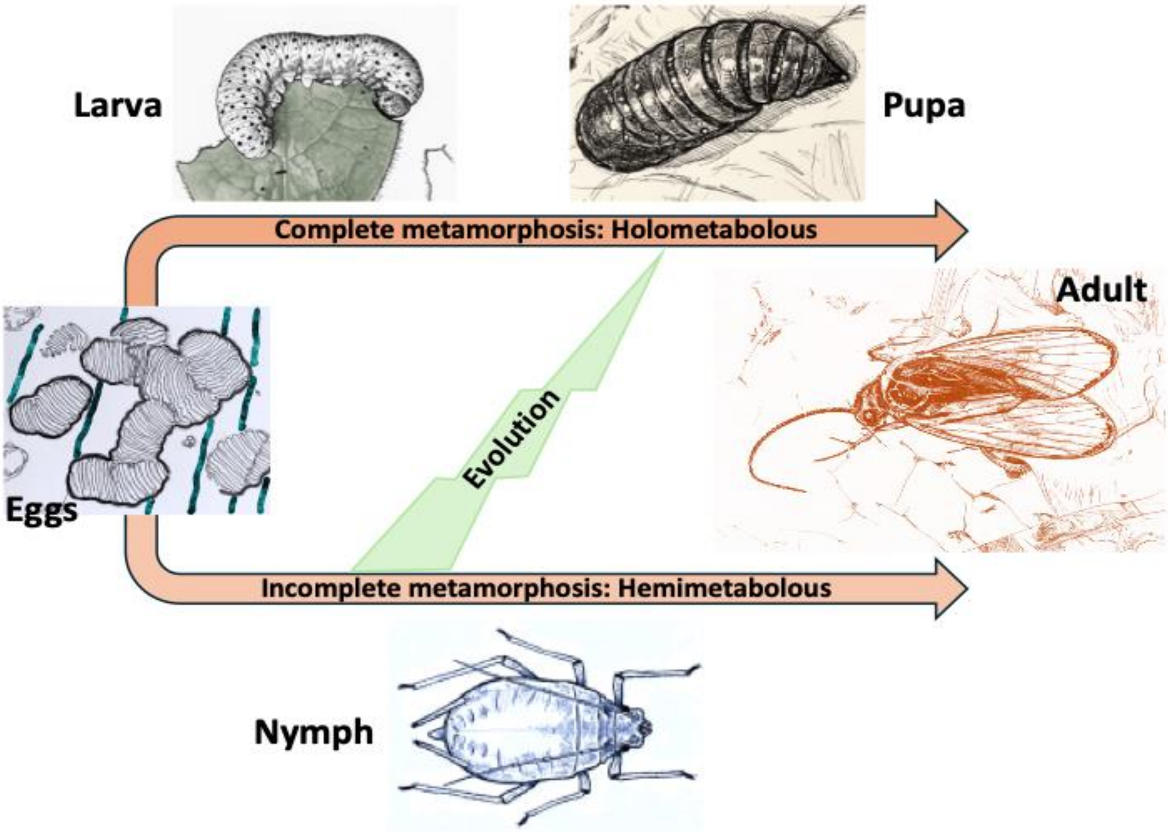

Figure 1: Insect life cycle with incomplete and complete metamorphosis strategies and proposed evolutionary implications.

In these metamorphosis processes, eggs are the initial stage in which embryo develops and then transform into larvae or nymphs in complete and incomplete metamorphosis. Larvae with usually worm-like shape feed and grow to inactive pupa stage undergoing major internal restructuring to become an adult. In incomplete metamorphosis, nymphs develop from eggs into sexually immature molting instars. The adult sexually mature stage shows reproductive organs and developed wings.

2. Fossil insects

Fossil insects at multiple developmental stages are well preserved in limestones and amber inclusions [3,4]. All pieces included in this study (Figs. 2-6) are part of author´s KGJ Colección (Ciudad Real, Spain) and were certified as authentic as previously reported [5,4]. Certificates of authenticity and/or legal origin were obtained from providers (e.g., Supplementary Information, Appendix 1 for rare Baltic amber inclusion with insect oviposition; Fig. 3A).

3. Fossil oviposition: Insect egg-laying scars and eggs

The first developmental stage in both complete and incomplete metamorphosis processes are insect eggs (Fig. 1).

For endophytic oviposition, adult female insects create oviposition scars by using specialized saw-like or spear-like appendages ovipositors to insert eggs into plant tissues with pattern marks as shown preserved in Carboniferous plant fossil (ca. 320 Mya) (Fig. 2). Common insects with endophytic oviposition include beetles, cicadas and damselflies [6].

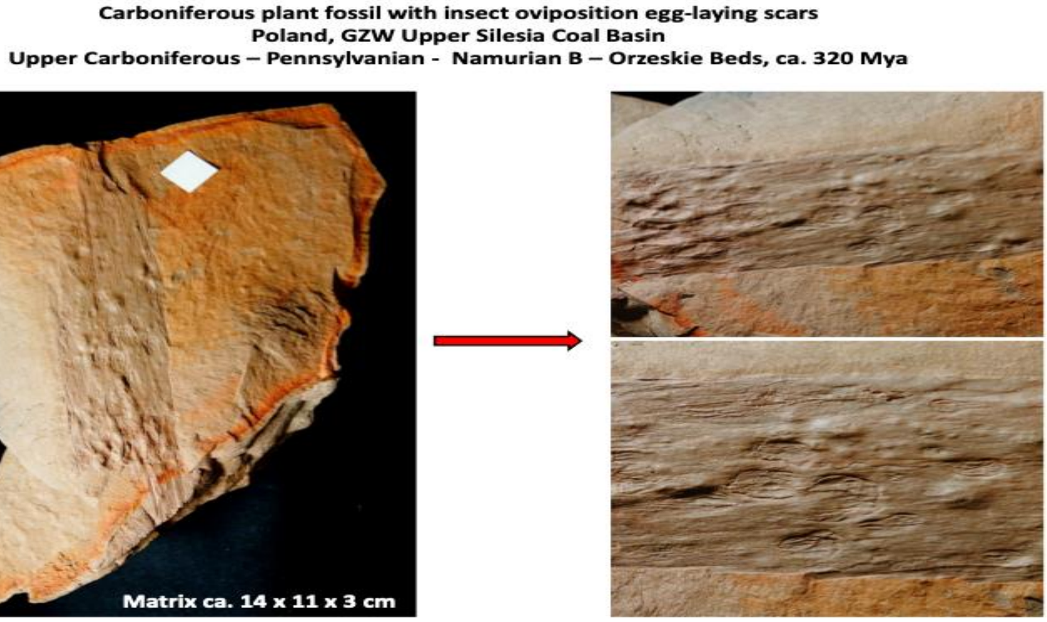

Figure 2: Carboniferous plant fossil with insect oviposition egg-laying scars. White square on stone matrix from Polish deposit is a size reference with 1.0 x 1.0 cm.

Some members of the true midge family (Diptera: Chironomidae) are capable of inducing plant galls, which serve as specialized habitats and food sources for their larvae [7]. Furthermore, and although rare in amber fossil inclusions, a true midge laying eggs was identified in Poland Baltic amber (Eocene, ca. 44 Mya) (Fig. 3A).

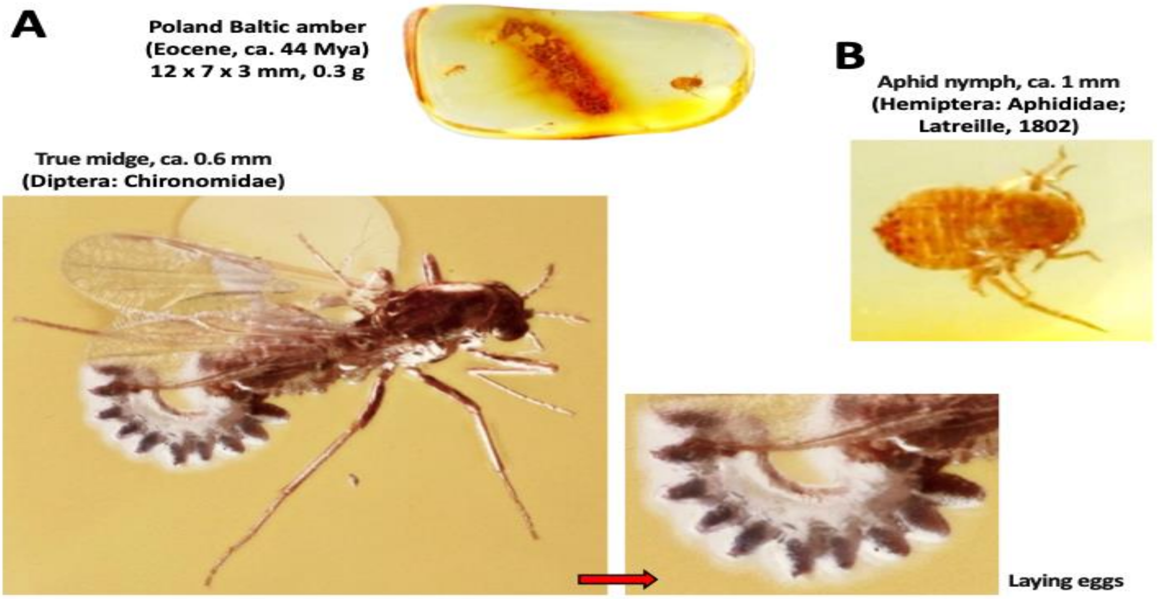

Figure 3: Eocene true midge laying eggs and aphid nymph amber syninclusions. Poland Baltic amber with a (A) true midge (Diptera: Chironomidae) laying eggs and an (B) Aphid nymph (Hemiptera: Aphididae).

4. Fossil hemimetabolous insects: Aphid nymph

Nymphs are a key stage in insect **incomplete metamorphosis** (Fig. 1) and an aphid nymph identified in Baltic amber with an adult true midge (Fig. 3B). The specimen displays the characteristic globular, soft-bodied morphology typical of aphid nymphs preserved in amber. The visible legs and the protruding abdominal structure, which appears to be a cauda or incipient cornicle, are diagnostic traits of the order Hemiptera.

These amber syninclusions may not only reflect coexistence between these insects, but also possible interactions as some true midges lay eggs near aphid colonies and larvae are predatory of aphids after hatching [8].

Fossil holometabolous insects: Diptera larva and pupa

The caddisflies (order Trichoptera) are insects with aquatic larvae and pupae serving as bioindicators of good water quality, and terrestrial adults [9] (Fig. 4A). Diptera larva shows the elongated segmented appearance vermiform body shape lacking developed thoracic legs that are morphological characteristics of many fly larvae (Diptera) found in Baltic amber (Fig. 4B).

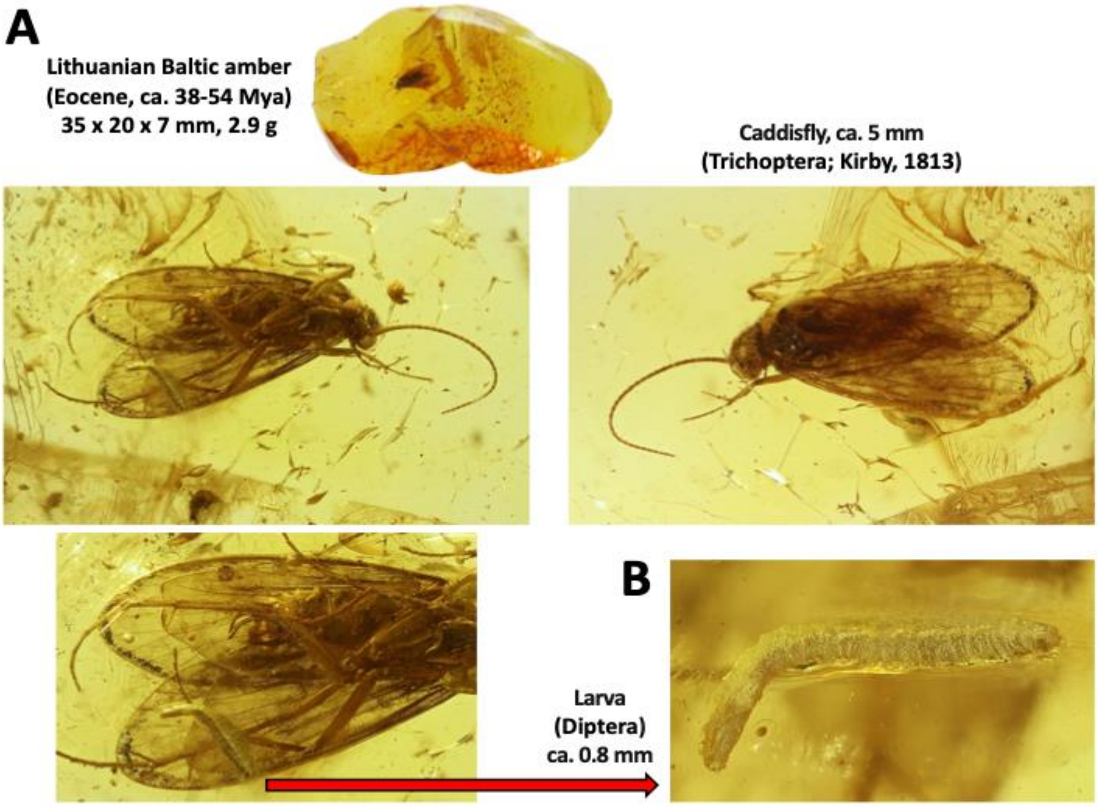

Figure 4. Eocene Caddisfly with Diptera larva. (A) Caddisfly (Trichoptera; Kirby, 1813) in Lithuanian Baltic amber syninclusion with a (B) Diptera larva.

A Diptera (unranked-Cyclorrhapha) pupa was identified in Dominican amber from Miocene (Fig. 5A). The specimen displays the characteristic barrel-shaped, segmented morphology typical of higher fly pupae, specifically the puparium stage. The darkened, hardened outer cuticle is a diagnostic feature of Cyclorrhapha flies, which utilize their final larval skin as a protective shell during metamorphosis [10]. The visible folds and lack of protruding appendages like those found in beetle or wasp pupae strongly point toward this order. Nevertheless, and although less probable, a member of the Hymenoptera order cannot be discarded.

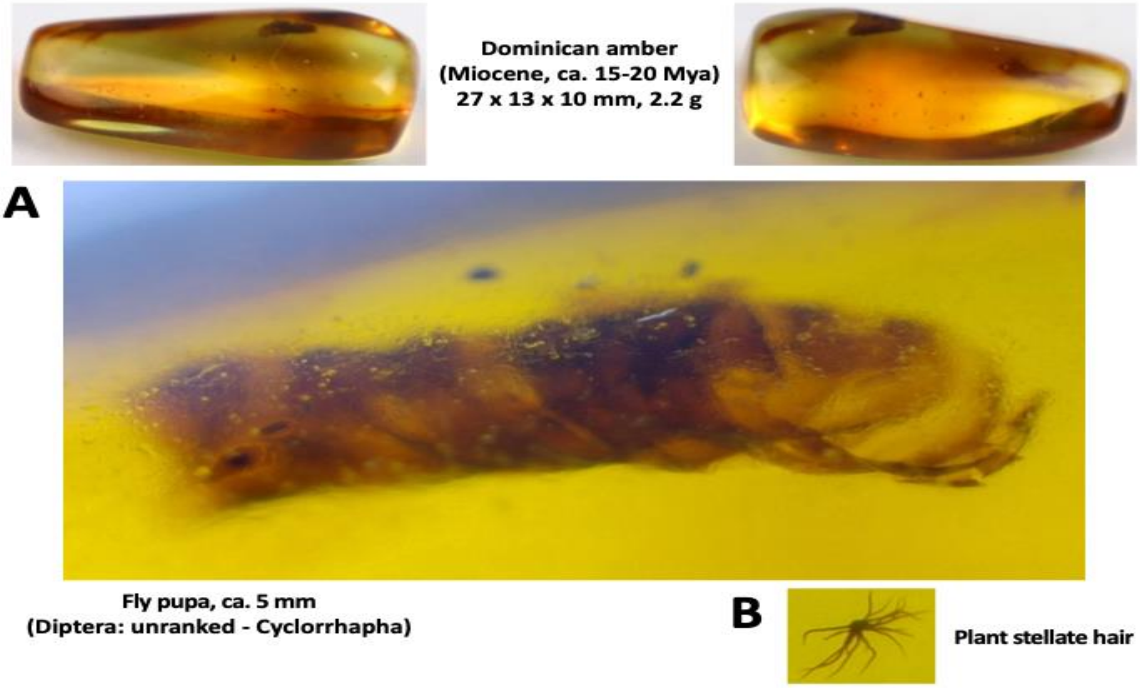

Figure 5: Miocene fly pupa and plant Stellate hair. (A) Fly pupa (Diptera: unranked-Cyclorrhapha) in Dominican amber syninclusion with a (B) plant stellate hair.

A plant Stellate hair with a characteristic multi-branched trichome or plant hair is commonly found in Dominican amber. These specialized botanical appendages from dicotyledonous plants often break off and become preserved in resin as star-shaped or spider-like inclusions. Its distinct radial symmetry and thin, elongated arms are consistent with the morphology of stellate trichomes found on the leaves of various plant families that thrived in the tropical forests of the Miocene. Stellate hairs are star-shaped, multicellular structures with 2-8 arms arising from a central point with branched epidermal trichomes, providing protection in plants against drought and herbivores by creating a dense, protective and reflective layer to decrease water loss and provide mechanical defense against insects [11].

5. Fossils in different stages of insect life cycle

The results of the study provided information documenting the identification of different stages in insect developmental processes (Fig. 6). Both complete and incomplete metamorphosis with three (hemimetabolous: eggs, nymph, adult) and four (holometabolous: eggs, larva, pupa, adult) developmental stages are represented in fossil inclusions. The study of these fossil inclusions provides information about the evolution of insect developmental stages.

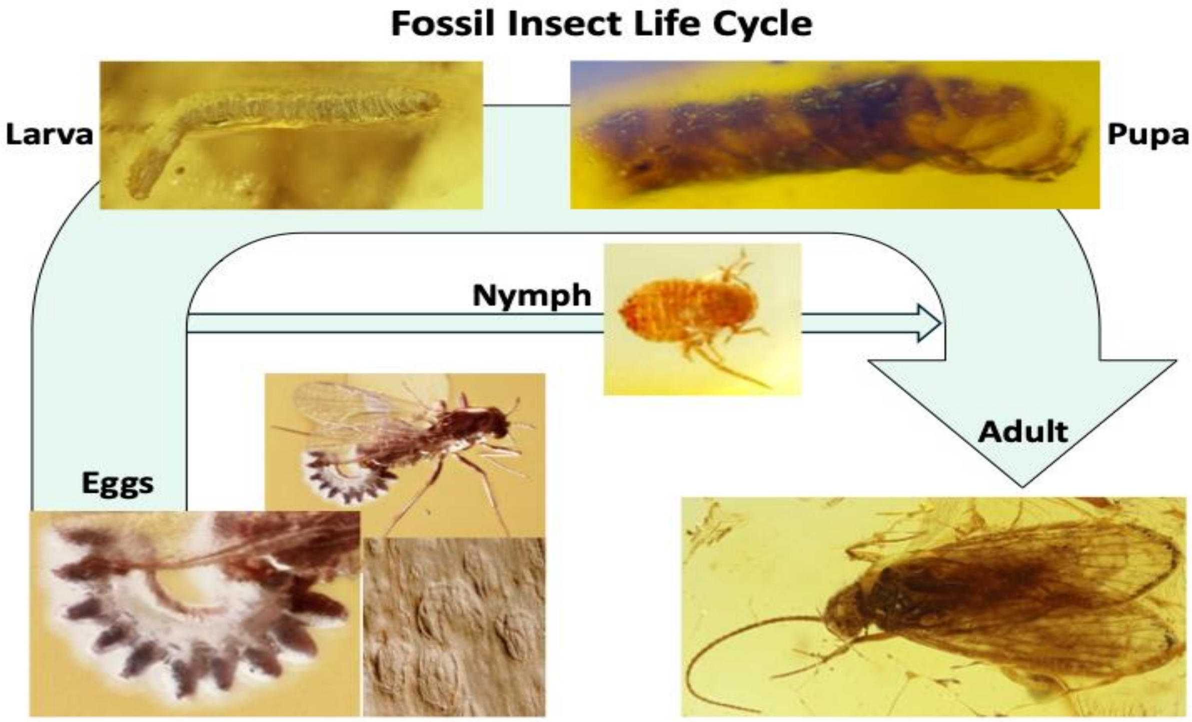

Figure 6: Conclusions representing insect life cycle in fossil inclusions. Images are from the fossils used in the study.

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Supplementary Information

Appendix 1. Certificate of authenticity for Baltic amber inclusion with insect oviposition (Fig. 3A). Provided by Jurassic Dreams (https://www.jurassic-dreams.com).

JURASSIC DREAMS

Certificate Number
150149

Issued on
03/15/2026

CERTIFICATE OF AUTHENTICITY

Midge LAYING EGGS & APHID Fossil Inclusion Genuine BALTIC AMBER

Scientific name *True midge Chironomidae laying eggs and aphid Aphidoidea (Baltic amber stone with fossil inclusion)*

Age Paleogene Period, Eocene spoch, (~44 Million Years)

Location Coasts of Poland, Baltic Sea

Formation Paleogene amber deposits under the Baltic sea

Observations: It weighs 0.3 grams. Measurements of stone 12x7x3mm, length of insect body and head ~ 0.6mm.

I hereby certify and guarantee the authenticity of this fossil piece, as well as the accuracy of its description.

The information provided in this certificate is given to the best of my knowledge and expertise, and considering the paleontologic data available to the present date. Should further scientific discoveries be made in the future, this document may be reissued with the novel relevant findings with regards to its description and classification.

The authenticity of this certificate can be verified by providing the unique certificate number at www.jurassicdreams.com/certificate-of-authenticity In addition, the certificate number on the top right of this document must match that of the security hologram. Removing the hologram destroys the paper and voids the certificate.

Juan Avilés Poblador
Vertebrate Paleontology Expert and Geologist
Alma Mater: Complutense University of Madrid and University of Alicante
University Degree Verification Code: [illegible]