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Bizarre Insect (Order: Strepsiptera; Kirby, 1813) with a unique biology

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Abstract
Strepsiptera comprise a group of inquisitive, obligate endoparasitoids. The parasitoids of Strepsiptera are enthralling insects, whose neotenic females completely endoparasitoid, laying eggs in or on other insects while free-living adult males with a very short lifespan. They are widespread in most terrestrial ecosystems and exhibit vast ecological and biological diversity with many specific types of adaptations. The insects termed as macrynobiont refers for lengthening the life of the host. Since some of the hosts are pests of crops like, rice, corn, oil palm, areca nuts, coconuts mangoes etc. they have the effectiveness for use as biocontrol agents.

Keywords: strepsiptera, endoparasitoid, macrynobiont

Introduction
The Strepsiptera (Greek strepsi, “twisted”; pteron, “wing”) commonly known as “stylops” encompass a group of entomophagous, obligate endoparasitoids with very unique morphology, biology, genetics and host–parasitoid relationship. They are cosmopolitan in distribution; largest numbers of species have been reported from the Australasian realm followed by the Oriental region. Owing to the endoparasitic life, the parasitoids are not easily noticed and remain an enigma to the entomologists. The males comprises unique hind wings with simple pattern of wing venation, fore wing reduced to look like a club like appendages termed as pseudohaltere, legs, rasp berry like eyes and flabellate antennae, superficially similar to flies, even though their mouths are not used for food, instead they are modified into sensory structures. They are non feeder, short–lived, usually surviving two to four hours. The male copulatory organ or aedaegus is minute and unique according to the different families of the order. Neotenic female except family Mengenillidae remains inside the host and completely endoparasitoid. Adult females are neotenic endoparasite projected inside a host body (rather than typical adult insects), 2–5 mm in length and without antennae, mouthparts, eyes, wings, legs and external genitalia. The cephalothorax encompasses of fused head, prothorax and mesothorax that obtruded through the host's synovial membrane, leaving the female's abdominal part inside the host’s body [6]. Virgin females are said to discharge a pheromone from the Nassonow organ which the male employments to find them with the help of the Hofender’s organ.

The families of Strepsiptera that are widespread in distribution are: Corioxenidae, Elenchidae, Halictophagidae and Stylopidae. The genera of parasitoids are restricted to the prevalence of the distribution of the hosts though the hosts in most cases are more widely distributed biogeographically than the parasitoids. Approximately 646 species [15, 16, 17, 18]. They are Corioxenos Blair, 1936; Dundoxenos Luna de Carvalho, 1956; Trizocera Pierce, 1909; Viridopromontorius Luna de Carvalho, 1985; Coriophagus Kinzelbach, 1971a; Halictophagus Curtis, 1832; Tridactylophagus Subramanian, 1932; Elenchus Curtis, 1831; Myrmecolax Westwood, 1861; Lychnocolax Bohart, 1951; Stichotrema Hofeneder, 1910a; Paraxenos Saunders, 1872 and Pseudoxenos Saunders, 1872.

Methods used for observation
The insects were completely inspected under a zoom stereoscopic trinocular magnifying instrument (demonstrate Olympus SZX16, Japan and CARL ZEISS Stemmi 2000–C, Germany) for discovery of outward injuries or patches showing ‘stylopisation’ on the both sides of host abdomen. Such host insects were sacrificed with two fine needles in insect saline water (0.67%) for procuring male adults and different larval stages, pupae, and gravid females with eggs or with triungulins. They come out from abdomen with a slight pressure in the saline water.

Biology
They have displayed one of the foremost unconventional and complex life cycles with extraordinary sexual dimorphism. The free living males have unique hind wing with least venation and the fore wing reduced to form pseudohaltere. The males also have legs, eyes, and flabellate antennae externally comparable to flies, in spite of the fact that their mouthparts are not utilized for nourishing, or maybe they are altered as tactile structures. They are short–lived, as a rule surviving two to four hours [4]. Females except family Mengenillidae remain inside the host. In most Strepsiptera the male pupates and extrudes while female extrudes and gets to be mature but some incidence where the male extrudes and pupates in fifth instar host nymph. These nymphs don't actually appear to signal the start of a molting cycle [6]. Premature host parasitized by male puparia eventually die due to fungal growth on empty puparia left after the adult males coming out [14]. Only the cephalothorax is visible from the outside (Fig-1); the rest of the cylindrical body remains inside the host and lacks all the features of an adult insect [3]. Males mate by disrupting the female's brood canal. Sperm exceeds through the opening of brood canal by a process known as hypodermic insemination [12]. Each female thus turns out many first instar larvae termed as triungulins that come out from the brood opening, which projects outside the host’s body (Fig 2). These first instar

larvae are very active and have well formed legs (which lack a trochanter) with long caudal setae and capable of jumping for a distance of two to three centimeter by using their caudal setae [1]. These larvae have a finite window of opportunity to locate a host. Entry within the host body is initiated with a combination of enzymatic and physical activity. Once inside the host, they undergo hyper metamorphosis and become a grub like legless larval form (second instar larva). They persuade the host to construct a bag–like structure termed as pupal bag inside. This structure, made from host tissue, ensures them from the safe protections of the hosts immune system. The larva goes through two more consecutive instars, with each molt exfoliating the old cuticle ("apolysis without ecdysis"), forming multiple layers around the larvae [9]. Male larvae form pupae after the last molt (Fig. 3), whereas female larvae enter the neotenic form directly [7].

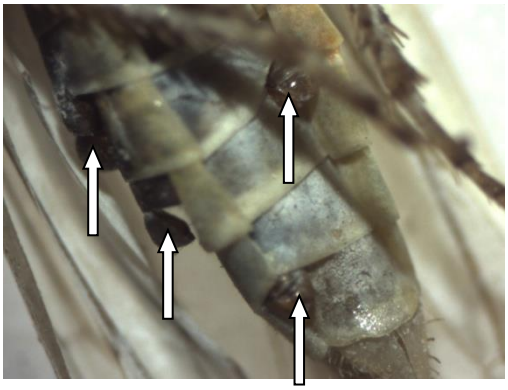

Fig 1: *C. spectra* stylopized by four endoparasitoids, *Halictophagus australensis* (Strepsiptera): an example of superparasitism. [Arrows indicating the location of strepsipteran endoparasitoids]

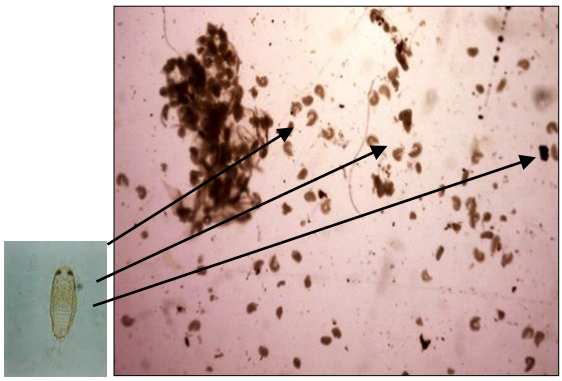

Fig 2: The first instar free living strepsipteran larvae, triungulin

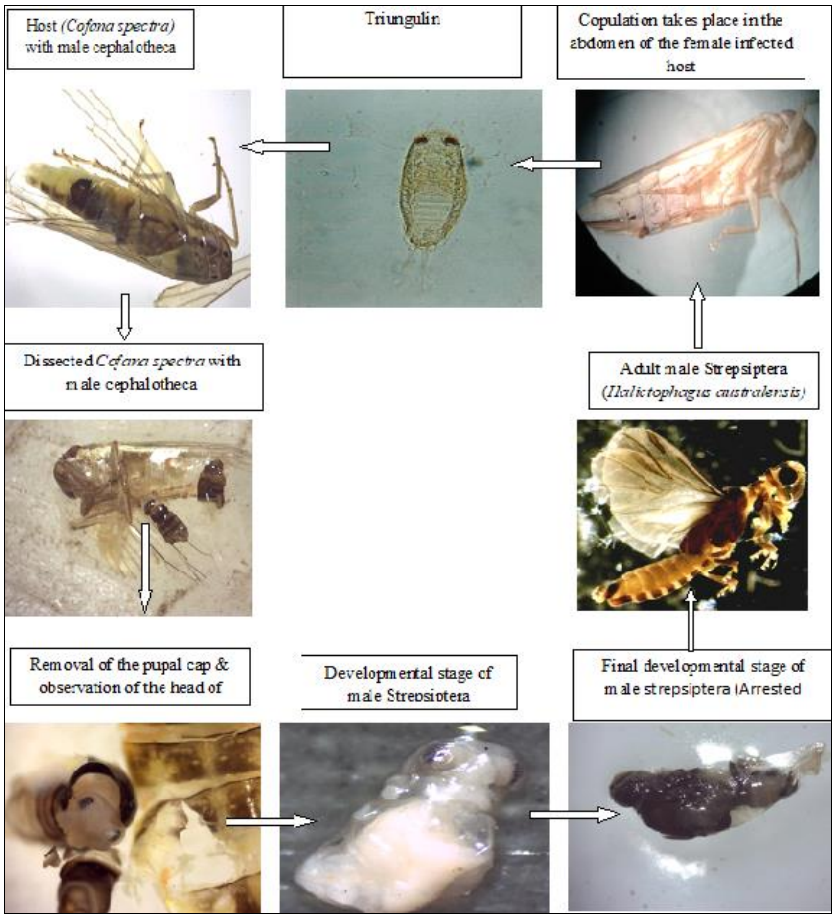

Fig 3: Life cycle of Strepsipteran Parasitoid (*Halictophagus australensis).*

Discussion

Impacts of stylopisation were examined prior on Hymenoptera. The foremost noteworthy changes due to stylopisation are that male hymenoptera tends to take after ordinary females and the pollen basket is diminished in females and males show a marked development. The interchange of characters in stylopised host has been referred to as "intersexes" [13]. Like hymenoptera parasitized Delphacidae (Hemiptera) (Table-1) were also thought to be "intersexes" [10, 11]. Stylopisation is known to cause numerous recognizable morphological, behavioral, dispersal and physiological changes within the hosts, even

- Driving to the arrangement of intersexes by alteration of the genitalia. The results of stylopisation incorporate changes in antennae, wings, facial colouration, pilosity, pollen collecting apparatus and length of the digestive tract.
- Stylopisation can too disable ovarian egg improvement, and cause lessening of egg number, essential, auxiliary and tertiary sexual characters and fertility of the host.
- Stylopised host insects frequently ended up less active and may gotten to be unfit of setting up nests within the case of a few Hymenoptera [20].

Although Strepsiptera is an endoparasite, it has a wide host range relative to its species abundance and requires a mobile host to complete its life cycle. Strepsiptera parasitizes a wide range of hosts belonging to the seventh order of insects. The most common host species are Hymenoptera and Hemiptera.

Table 1: Records of stylopised Hemipteran host in India.

Host	Family &subfamily	Position of stylopisation
Atkinsoniella opponens (Walker, 1851)	Cicadellidae	Stylopisation mark on 6th to 9th sternite segments. There was no stylopisation encountered in the tergite segment till now.
Exitianus nanus (Distant, 1908)	Cicadellidae	Only one stylopised host was observed. Stylopisation took place at the lateral portion of the 7th sternite.
Exitianus indicus (Distant, 1908)	Cicadellidae	Stylopisation mark was found at 7th to 8th sternite segments.
Cofana spectra (Distant, 1908)	Cicadellidae	Stylopisation marks were observed on two different locations. One type encountered at the 5th to 6th tergite segments, considered as a male stylops and another one was encountered at the 6th to 9th sternite segments, considered as female stylops. Both types of stylopisation marks noticed on 15 numbers of specimens.
Nilaparvata lugens (Stål, 1854)	Delphacidae	Only two stylopised BPH were observed. Both stylopisation were encountered at the 4th abdominal tergite.
Sogatella furcifera (Horváth, 1899)	Delphacidae	Stylopisation marks were observed on two different locations. One type encountered at the 6th to 8th tergite segments, considered as a male stylops and another one was encountered at the 6th to 9th sternite segments, considered as female stylops.

At the early stage of host development Strepsiptera are not very active but have a exclusive immune avoidance mechanism. They form a pupal bag in the host cuticle. Strepsiptera are accounted to exercise control over the population level of host insect pests. The rate of parasitism fluctuates from 10% to 65% depending on several factors including temperature, humidity, rainfall and locations. Strepsiptera have the potential to be successful bio-control specialists but it is very difficult to practical implementation due to their low searching ability. Still such a venture is already in progress in Papua New Guinea where the female Strepsiptera, *Stichotrema dallatorreanum* Hofeneder is being used as a biocontrol agent for the long-horned grasshopper *Segestidea novaeguineae* [19]. Various questions almost hereditary qualities, sex deciding instruments, host location, various host spectrum, and change of host physiology in this baffling arrange of bizarre insect order still stay unanswered. One key feature is that, when parasitized by Strepsiptera, the host's life cycle is lengthened as long as they require to mature. This difference between strepsipterans suggests a trichotomous hypothesis concerning insect parasitoids, and the term macrynobiont (*macryno*, "lengthen"; *bionts*, "life"), refer for lengthening the life of the host due to Strepsiptera [8].

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