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Foraging and mating behavior of the butterfly *Archonias brassolis tereas* (Godart, 1819) (Lepidoptera: Pieridae: Pierinae) in two sites in Southeastern Brazil

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Abstract
This study describes some aspects of the foraging and mating behavior of the butterfly *Archonias brassolis tereas* recorded in two sites at coast of São Paulo State, Brazil, near the hills of Serra do Mar. Adults of this species forage in ten species of Asteraceae: *Cyrtocymura scorpioides*, *Bidens alba*, *Chromolaena maximiliani*, *Austroeupatorium inulaefolium*, *Vernonanthura beyrichii*, *Mikania hatschbachi*, *Mikania lundiana*, *Elephantopus mollis*, *Chromolaena laeve*, *Chromolaena laevigatum*, and two non-asterace species: *Cupania oblongifolia* (Sapindaceae), and *Inga marginata* (Fabaceae). The sexual dimorphism is weak with females being slightly heavier than males. Females can copulate with more than one male. Although courtship displays where observed in females foraging on flowers it was not seen in the recorded mating.

Keywords: mating behavior, perching strategy, territoriality, thermoregulation

1. Introduction
The butterfly *Archonias brassolis tereas* (Godart, 1819) (Pieridae) is particularly common in the Jurubatuba and Quilombo River valleys in the continental area of the municipality of Santos, Sao Paulo, Brazil. In these same areas, the body mass allocation, of males of this species was studied by Francini and Sobral Souza [1] later followed, by the study of the male territorial behavior by Francini *et al.* [2]. These studies showed that males can be classified in different groups in relation to their thoracic mass allocation, with perchers being light and agile and patrollers heavy and slow. Territorial behavior in perchers began during early morning when perched males give quick response to other flying insects and territory length tends to decrease with increase of male density in the population [2].
Part of its life cycle was described at Serra do Japi, Sao Paulo, Brazil, by Mota *et al.* [3]. However, for this species, issues not yet studied include adult feeding, and reproductive behavior. To complement all these works, the objective of this study was to describe aspects of the foraging and mating behavior of *A. b. tereas*.

2. Materials and Methods
The records were made in two sites in the coast of São Paulo State, Brazil near the hills of Serra do Mar. The first site is the Quilombo river watershed (coordinates: 23°51'25.22" S, 46°20'55.37" W) (see [4] for details) and the second site is the Jurubatuba river watershed (coordinates: 23°52'25.13"S 46°18'47.50" W) (see [2] for details).
The degree of polyandry was estimated using the average number of spermatophores found in the female copulatrix bursa [5].

3. Results
3.1 Foraging behavior. At study area, the butterfly *Archonias brassolis tereas* forage on flowers of plants of the family Asteraceae: *Cyrtocymura scorpiodes* (Fig. 1A), *Bidens alba* (Fig. 1B), *Chromolaena maximiliani* (Fig. 1C), *Austroeupatorium inulaefolium* (Fig. 1D), *Vernonanthura beyrichii* (Fig. 1E), *Mikania hatschbachi* (Fig. 1F), *Mikania lundiana* (Fig. 1G), *Elephantopus mollis*, *Chromolaena laeve*, and *Chromolaena laevigatum*. In this area, flowers of *Bidens alba* area available during all seasons. Other species blooms only during

autumn and early winter. Two others non asterace species: *Cupania oblongifolia* (Sapindaceae) (Fig. 1H), and *Inga marginata* (Fabaceae), are also used as nectar source.

Compared with other butterflies, the foraging behavior of males and females of the *A. b. tereas* is calm. When feeding on nectar these butterflies stay a long time on the same flower or inflorescence, always exposing their wing pattern and permitting the approximation of human observers up to 50 cm without disturbing their behavior.

On June 17, 2008 at VRQUI site, the continuous recording of individuals of this species, from 07:00h to 17:00h, showed that after 10:00h the number of butterflies increased due to the abandon of territorial behavior by males when several individuals of both sexes are seen side by side in neighborhood flowers (Fig. 1 I). In another 28 non-continuous observations, individuals of both sexes were observed foraging in flowers in the late morning.

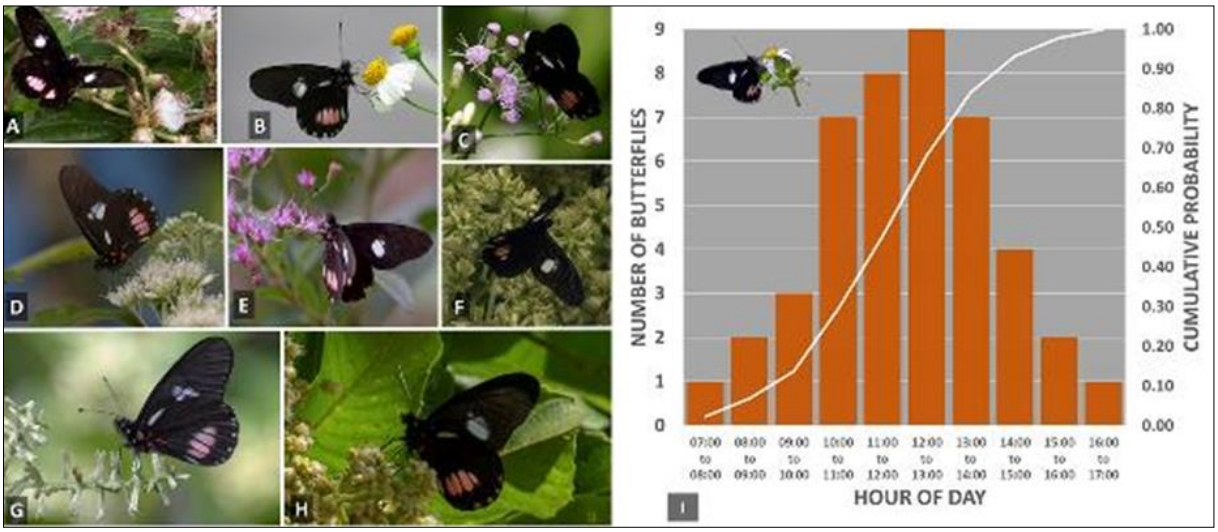

Fig 1: Individuals of the butterfly *Archonias brassolis tereas* foraging on flowers of inflorescences of plants at VRQUI site: (A) *Cyrtocymura scorpiodes.* (B) *Bidens alba*. (C) *Chromolaena maximiliani*. (D) *Austroeupatorium inulaefolium*. (E) *Vernonanthura beyrichii*. (F) *Mikania hatschbachi.* (G) *Mikania lundiana*. (H) Cupania. (I) Number of *Archonias brassolis tereas* butterflies on flowers of *Bidens alba* (Asteraceae) at VRQUI site on June 17, 2008, showing that foraging on inflorescence flowers concentrates at hottest hours of day.

3.2 Number of ovules and spermatophores in wild females. The ovule is egg-shaped with a funneling at apical rim region (Fig. 2 A). The number of ovules in five dissected females ranged from 49 to 116 (mean = 70.8 ovules; sd = 26.73 ovules). Ovule length ranged from 1.17 to 1.23 mm (mean = 1.10 mm; sd = 0.013 mm; n = 30) and diameter from 0.57 to 0.61 mm (mean = 0.60; sd = 0.012 mm; n = 30). Prominent nodules of the apical rim ranged from 5 to 7 (median = 6; n = 30) (Fig. 2 B-C). One female had no spermatophore, two had one spermatophore, and two, two spermatophores which gives a degree of polyandry of 2.50.

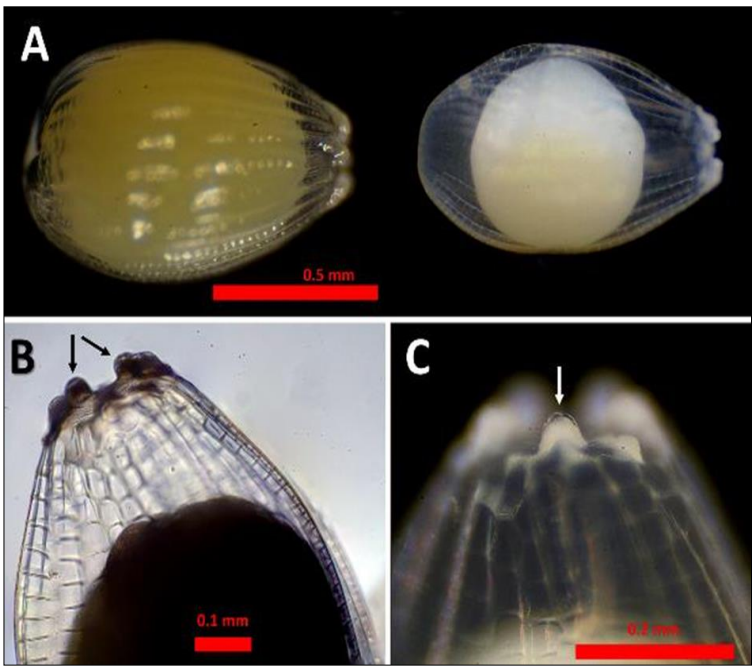

Fig 2: Ovule of *Archonias brassolis tereas*. (A) Two minutes after extraction from ovariole, and (B) 10 minutes after immersion in 1% NaCl solution to show its longitudinal ribs. (B-C) Details of the micropylar region showing the prominent nodules (arrows) of the apical rim using light (B) and dark (C) field illumination.

3.3 Courtship behavior

Mostly courtship records were made when butterflies were foraging on flowers. When male harasses a female landed, it flights continuously behind it (Fig. 3 A-H). Generally, after a while, both flights quickly (Fig. 3 I-J), sometimes with physical contact between their bodies (Fig. s 3 K). However, female response (n = 28) was to reject the male, generally flying away to another inflorescence (n = 23). When the harassment is strong and continuous both fly away in a vertical spiral (n = 5) (Fig. s 3 L) when the pair falls apart, one of them returning to the flowers where it was drinking nectar. It happens when more than one male harasses a female, generally with them fighting in the air and the female returning to its foraging. Some males are very insistent and remain harassing the female for more than a minute (n = 16), but with the unresponsiveness of it they return to feeding, in a cycle that can be repeated many times. The sensory system used by males to recognize conspecific females does not appear to be very accurate. In two different dates, we recorded a male of *A. b. tereas* that began a courtship with a female of *Parides tros* foraging in flowers of *Austroeupatorium inulaefolium* and *Inga marginata* (Fig. 3 M), which lasted around five seconds. Also, a male may be mistaken for a female and then he may be harassed by another male (n = 6). These encounters are usually quick, lasting less than 5 seconds, and the upshot is that they pull back and forage again.

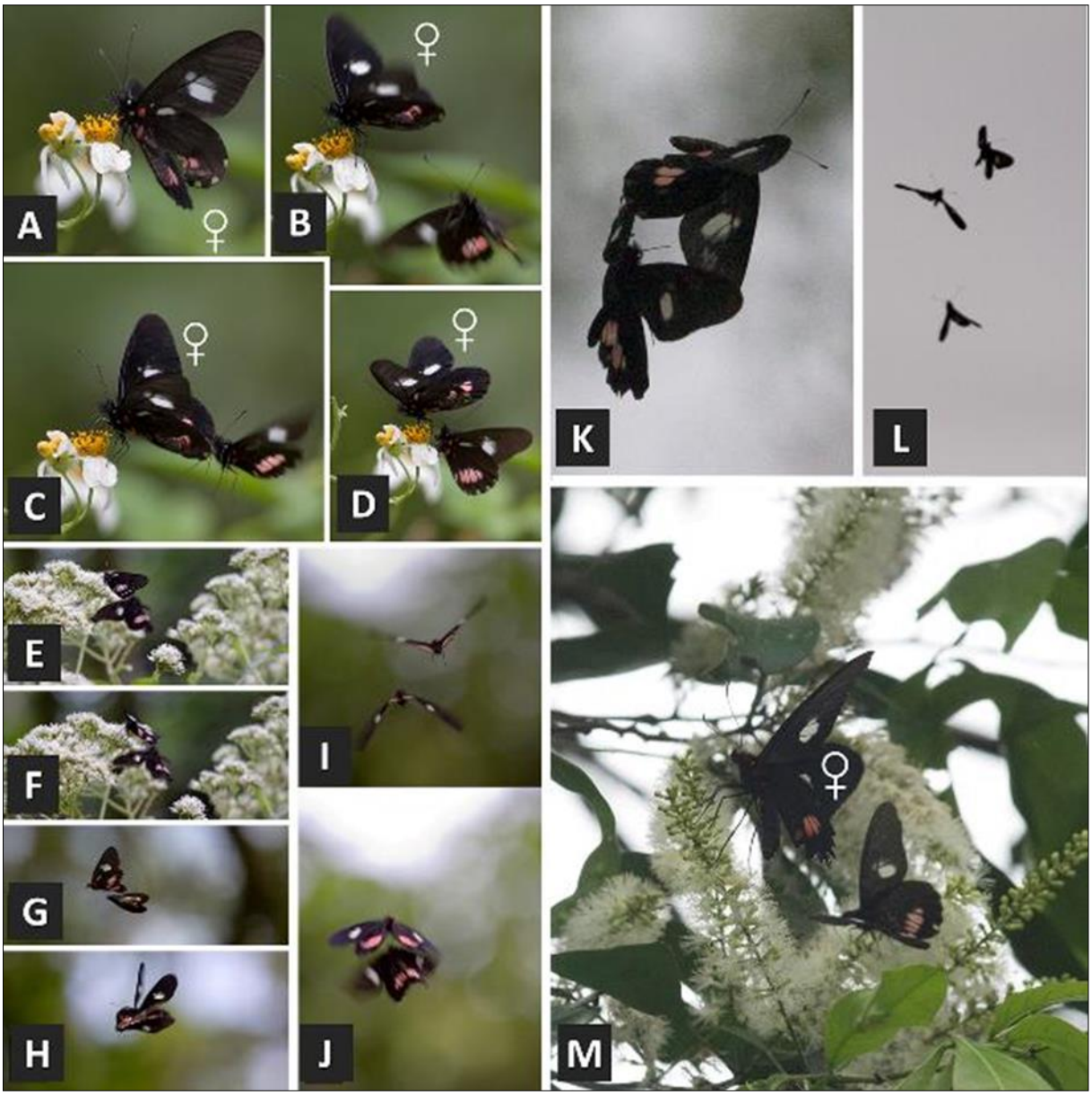

Fig 3: (A-D) Displays of a male of *Archonias brassolis tereas* harassing a female foraging in inflorescences of *Bidens alba*. (E-F) The same in *Austroeupatorium inulaefolium*. (G-J) Interaction lasted only three seconds when both flew away from the field of vision. (K) During these flights the butterflies have physical contact between their bodies. (L) Displays of a spiral flight including two males and a female which was foraging in inflorescences of *Bidens alba* in a interaction which lasted 15 seconds. (M) A male of *Archonias brassolis tereas* harassing a female of *Parides tros* (Papilionidae) which was foraging on flowers of *Inga marginata*.

Color wing pattern of both sexes is very similar (Fig. 4). This could be explained by the fact that if males depend solely on vision for recognition of females.

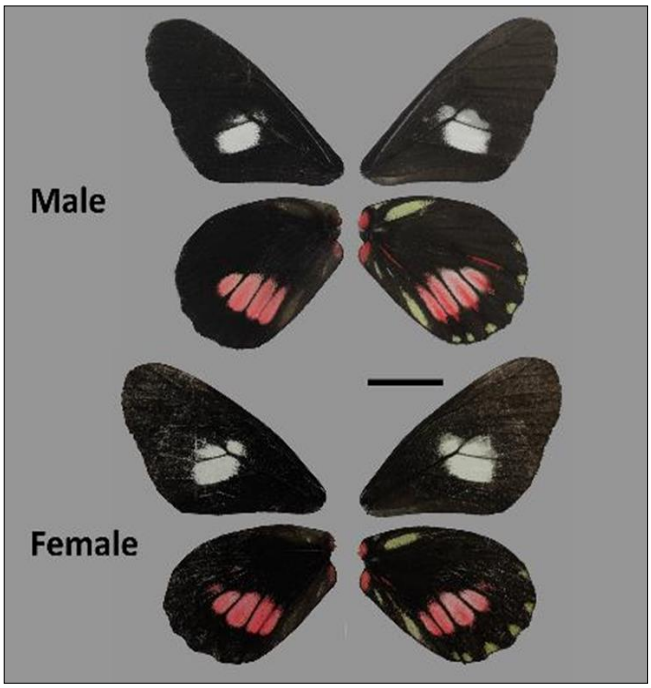

Fig 4: Wing patterns of individuals of both sexes of the butterfly *Archonias brassolis tereas* showing high their similarity. Scale bar = 10 mm. Dorsal surface at left.

3.4 Mating behavior. On August 8, 2012, we observed an already initiated copulation at Quilombo river watershed. We sighted the couple at 08:45h landed on a leaf of *Hedychium coronarium* (Fig. 5 A). The couple remained immobile during all period of observation (30 minutes) despite the moving people around them. Biometry of both individuals showed that male had a fresh body mass of 0.0713 g and female a fresh body mass of 0.1168 g, which is 1.66 times heavier. On June 8, 2019 at 09:50h, a second mating was observed at Jurubatuba river watershed. The female was flying along the dirt road some five meters high for about 50 meters. Suddenly she was intercepted by a male who quickly mated with her. At 09:53h the couple was landed on a leaf. At 09:54h, they flew to another tree 30 m apart (Fig. 5 B) flying again at 09:56h (Fig. 5 C) when the male was carried by the female. Finally, at 09:58h, they landed on leaves of another tree (Fig. 5 C), ten meters apart remaining immobile still 10:15h when they were collected. Here, male had a FW length = 28 mm (fresh body mass of 0.0800 g) and female a FW length = 32 mm (dry body mass of 0.1200 g), which was 1.50 times heavier.

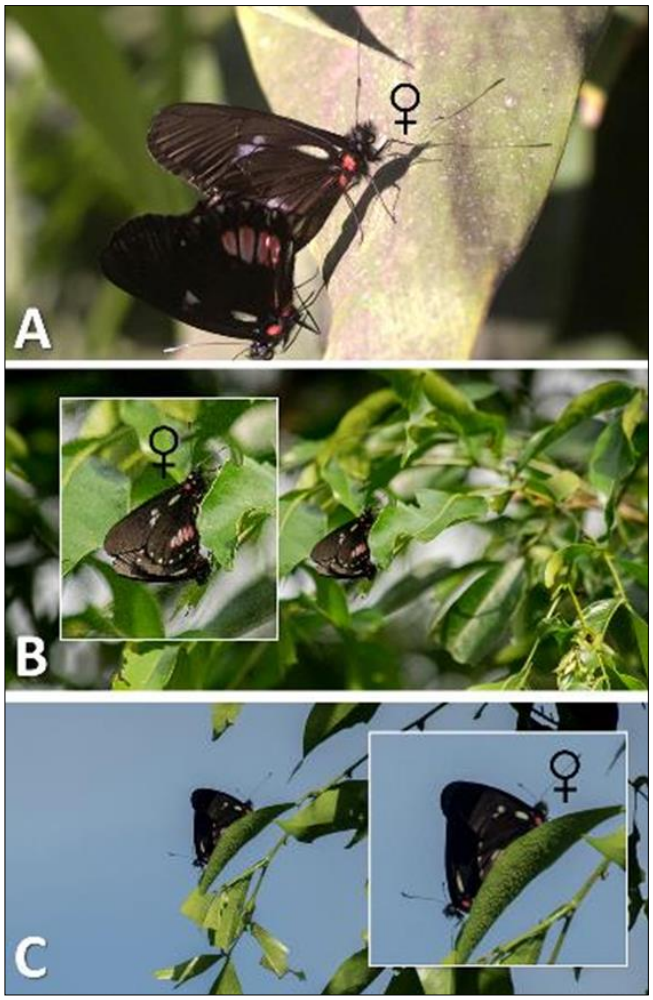

Fig 5: (A) The first mating couple of *Archonias brassolis tereas* found on August 12, 2012 at 08:50h AM, landed on a leaf of *Hedychium coronarium*. Both individuals had newborn aspect. The couple remained immobile during all period of observation (30 minutes) despite the moving people around them. (B) The second couple of *Archonias brassolis tereas* observed on July 8, 2019. At 09:50h AM, we observed a female who was flying along the dirt road some five meters high for about 50 meters. Suddenly she was intercepted by a male who quickly mated with her. At 0953h AM we saw the couple landed on a leaf. At 09:54h AM, the couple flew to another tree 30 m apart, flying again at 09:56h AM, when we could see that male was carried by the female. (C) Finally, at 09:58h AM, they landed on leaves of another tree, 10 meters apart remaining immobile still 10:15h AM, when they were collected.

4. Discussion

4.1 Foraging behavior. Both sexes go to the flowers on the morning end, a pattern yet recorded for other butterfly territorial species (e.g. *Eueides pavana*, unpublished data, and *Actinote zikani*, [6]).

4.2 Number of ovules and spermatophores in wild females: Ovule length and diameter measurements are quite similar of the two eggs studied by Mota *et al*. [3].

In European pierid species, the degree of polyandry values ranged from 1.11 to 2.30 [7-9], meaning that the females can mate two or more times which can increase the average direct net fitness gain [10, 11]. Earlier, in a met analysis of Lepidoptera species, found that in all of them, females are polyandric [12].

The mating system of *A. b. tereas* was classified as being type of resource defense polygyny but when the degree of polyandry is bigger than one, we have a case of polyandry [2, 13]. These two possibilities lead them to interpret the *A. b. tereas* mating system as being polygamic.

4.3 Courtship behavior: The exclusive use of vision in courtship appears to be the pattern in other pierid species [14]. In this case, in areas of relatively high male concentrations, males can spend much of their time chasing each other [15]. In perching species, the vision plays a crucial role in the identification of other flying insects which enter in the field of vision of the male. It appears that the size and color pattern, associated with flight speed, plays an important role as identifiers for a potential partner [16]. Experiments done with larger-than-normal (supernormal) female models indicated that they elicited stronger responses from the males [23].

In relation to females, there are eight different types of rejection postures, with the basic rejection behavior of female Pieridae being that of the vertical positioning of the abdomen, keeping the wings in a horizontal position, parallel to the substrate [16].

4.4 Mating behavior: The low number of records of copulations is relatively common in butterflies [6, 18, 19]. Events of this type in the wild are notoriously difficult to observe, as nearly all female butterflies' mate soon after emerging from the pupa, and in consequence, most active females in a given population have already been fertilized [20]. Therefore, the duration of female availability can affect the mating system [15]. Our results are concordant with Baker's results [21] for *Inachis io* and *Aglais urticae* nymphalid territorial butterflies that suggested that an edge and corner sites, as found in roads, have advantage for a male to locate a migrating female which is searching for oviposition sites flying along edges for some distance in their search. The observations that a foraging male can harass another male beginning a mating display could be explained by the fact that if males depend solely on vision for recognition of females, which appears to be the pattern in other pierid species [14], this could explain why one male flirts with another male. In this case, "in areas of relatively high male concentrations, males can spend much of their time chasing each other" [14]. The reason that perches of males were in spots where sky visibility is high is because it increases the probability of female visualization (reproduction) and facilitates the reception of solar radiation (thermoregulation). In *Actinote* species clashes between territorial males usually bring the contenders to the ground which was not observed for *A. b. tereas* (e. g., *A. pellenea* [22] or *A. zikani* [6].

In 23 butterfly European species studied by [7], they observed that female carries the mating partner in flight more than 95% of the of the occasions. However, in a prior met analysis using worldwide data, [16] stated that there was a great variation in this behavior.

5. Conflict of interests
No conflicts.

6. Further information
The work is not financed within a project.

7. Author's contributions
All authors contributed equally.

8. Funding source
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