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The origin of honey bees' life: A viewpoint

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Abstract
Honey bees, *Apis* spp., are very important for our environment, economy and health. Honey bees are considered as an ideal model for many biological and physiological studies. Enormous studies have been conducted on honey bees to cover a wide range of aspects including; biology, behavior, ecology, and genetics. However, relatively few studies have been performed to explain the exact origin of honey bee life (The beginning of honey bee life). In most social insects there are a transition between social life and solitary life but in honey bees the solitary life is completely diminished. So far, the transition from solitary life to full sociality in honey bees is not well understood. Here, a mini review about evolutionary studies on honey bees followed by an analytical viewpoint about the origin of honey bee life has been presented. The difficulties in understanding the origin of honey bee life are also highlighted.

Keywords: Honey bees, *Apis mellifera*, evolution, sociality, origin.

1. Introduction
It is known that honey bees are social insects, that means the presence of group of individuals with specific characters, castes and roles live together in a common nest to complete their life cycle. On the other side, there are solitary insects, male and female insect can complete their life cycle without the need for a specific nest or cooperation with other individuals. It is commonly thought that the ancestors of honey bees are solitary insects and some genetic investigations supported this idea [1], and others thought that the origin of the bees is the sphecid wasps [2]. Honey bees are different than other social insects or even solitary insects in their life, and very few studies have been conducted for studying the beginning of honey bee life. In this viewpoint article, a potential scenario for the life of honey bees has been presented.

2. Mini-Review about evolutionary studies on honey bees:
Most of the pervious evolutionary studies on honey bees were focused on the behavioral aspects of honey bee workers. The behavioral evolution (e.g. nest and comb structure, dance type and sound) for different honey bee species using phylogenetic analysis was studied [3]. Others studied the dance language of honey bees [4]. The evolution of castes was also covered [5] and other studies focused on the evolution of worker sterility [6]. Moreover, the development and feeding of honey bees were highlighted [7] as well as the evolution of antimicrobial peptide in honey bees was investigated [8]. Divergent roots for Western and Eastern honey bees were suggested [9]. Recently, it is suggested that the origin of honey bees, *Apis mellifera*, is Asia instead of Africa as thought in the past [10]. A detailed review for bee phylogeny was presented [11]. Some theories and simulations were presented for the evolution of social insects [12, 13, 14]. The exact description of the mechanism at which the honey bee life was started is not widely covered through studies.

3. Solitary vs. social life
Insects with solitary life have relatively simple life cycle where only one male and female are required for the beginning of a successful life. After mating, females lay their eggs in a safety place and near to their offspring food. Then, the offspring depends on themselves without the need of any help from their parents [2]. In case of social insects, mainly wasps, ants and some bee genus, one female and one male are required for the beginning of the social nest. After mating, females (queens) start in constructing the nest and lay some eggs which develop, subsequently, into sterile females (workers) and the workers then take charge of all tasks inside the nest except egg laying (this task is exclusively for the queens). These social colonies sometimes survive to one year or more and generally at autumn all members die except some females and males which repeat the life cycle again [2]. In the previous examples, females have

the ability to start the life cycle by constructing the nest and egg laying or by egg laying in a safety place. Also, in case of social insects, females have the ability to construct their nests using special features in their body (e.g. special glands, suitable mouth parts, good flight ability etc.). But the situation is completely different in honey bee, *Apis* spp, life.

4. Honey bee life

Honey bees cannot start their life as in other social insects because; 1) honey bee queens cannot construct the nest alone because there are no wax glands on their abdomens (about characters of the queens see[15]) and one queen alone cannot construct a wax comb due to the hexagonal shape of wax cells as well as the construction of wax combs requires a lot of energy, about 3.8 kg of honey is required for producing 453 g of beeswax[16], 2) honey bee queen cannot feed herself on royal jelly or on nectar, 3) honey bee queen cannot feed her offspring because honey bee queen has not the ability to perform foraging behavior and there is no pollen baskets on her hind legs to collect the pollen, and the queen has short tongue therefore she cannot collect nectar, 5) honey bee workers when emerged from the cells they cannot do foraging directly and they, in normal case, perform foraging behavior after 21 days from the emergence time so who could feed them during this period, and 6) honey bee queen cannot take care of the eggs till hatching as well as brood rearing due to the specific requirements during the incubation period, temperature between 33 ºC to 36 ºC [17] and relative humidity above 75% [18], and one queen cannot provide the nest with these conditions. Therefore, one honey bee queen cannot under any circumstance start the life cycle of the honey bee colony as in other social insects. Thus, how did honey bees start their life?

It is well known that honey bee colonies reproduce by swarming, that means some workers move from the colony with virgin or mated queens to a new place. Then these workers cooperate together to build a new nest while the role of the queen is only for egg laying and pheromonal control [19]. Fig.1 compares between the life of solitary and social insects, and honey bee.

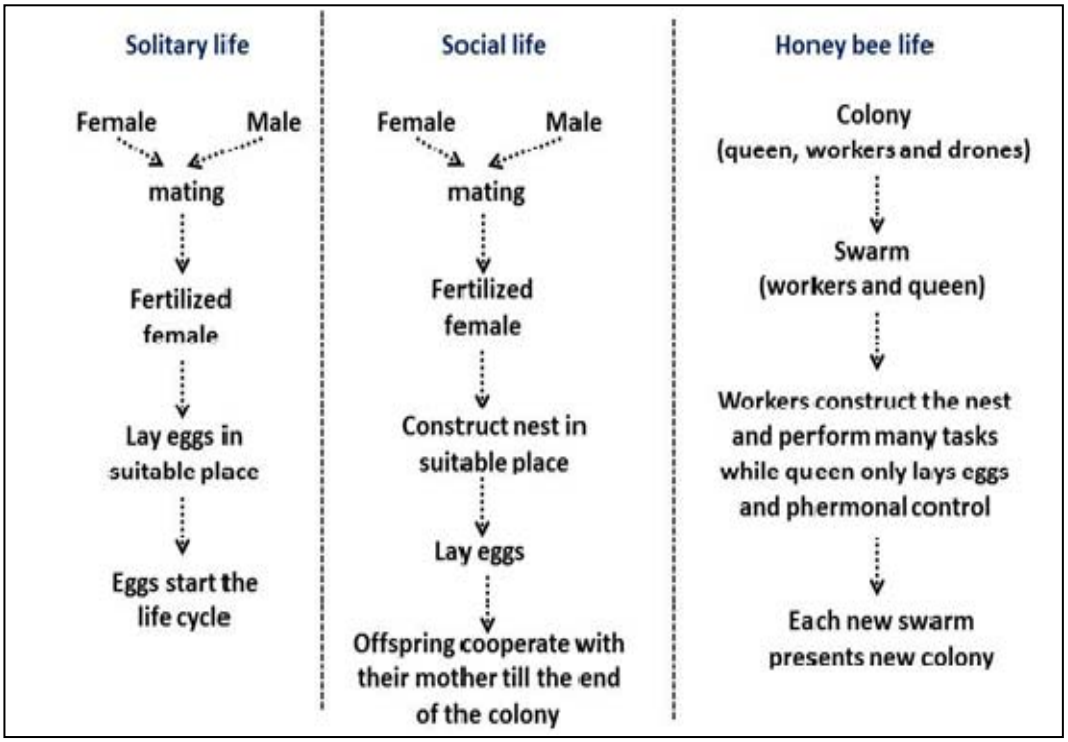

Fig 1: General steps of life cycle for solitary insects, social insects and honey bees.

Therefore, I suggest the following scenario for the beginning of honey bee life. Honey bees started as in other social insects after that a great shift only in behaviors (namely swarming behavior as the key change) was happened. In this scenario, I think honey bees had a normal life cycle as in other social insects till a great shift in their life was happened where honey bees learned to swarm. In other words, honey bee queen was able to construct her own nest to start the colony till honey bee workers learned swarming to construct a distinctive wax nest in trees, rocks and cavities.

Also, it is expected that honey bee workers learned the construction of combs with hexagonal wax cells after their learning to swarming, because the construction of wax combs with hexagonal cells requires a large number of workers as well as a sufficient amount of food which cannot easily be done by a small group of bees. Under swarming conditions, honey bees fill their crops with honey or nectar and a large number of bees flight to a specific place to start nest construction. Thus, the experience of nest construction, in its present form, can only be gained after swarming behavior. Moreover, by the suggested scenario, honey bees were not a honey-storing insect till their learning to swarming behavior and nest construction behavior. Because without hexagonal nest cells, storing large amounts of honey is too hard and honey storing needs also a large number of bees. Thus, the workers were able to learn other behaviors, including nest construction, food storing and sealing the wax cells after their learning to swarm. Moreover, the queens lost some body characteristics including; pollen baskets, wax glands, scent glands and others by time. Additionally, swarming behavior gives an extension to the life of honey bee colonies where the mother colony can live for a long time and multi-swarms can result from it. The steps of the suggested scenario are shown in Fig. 2.

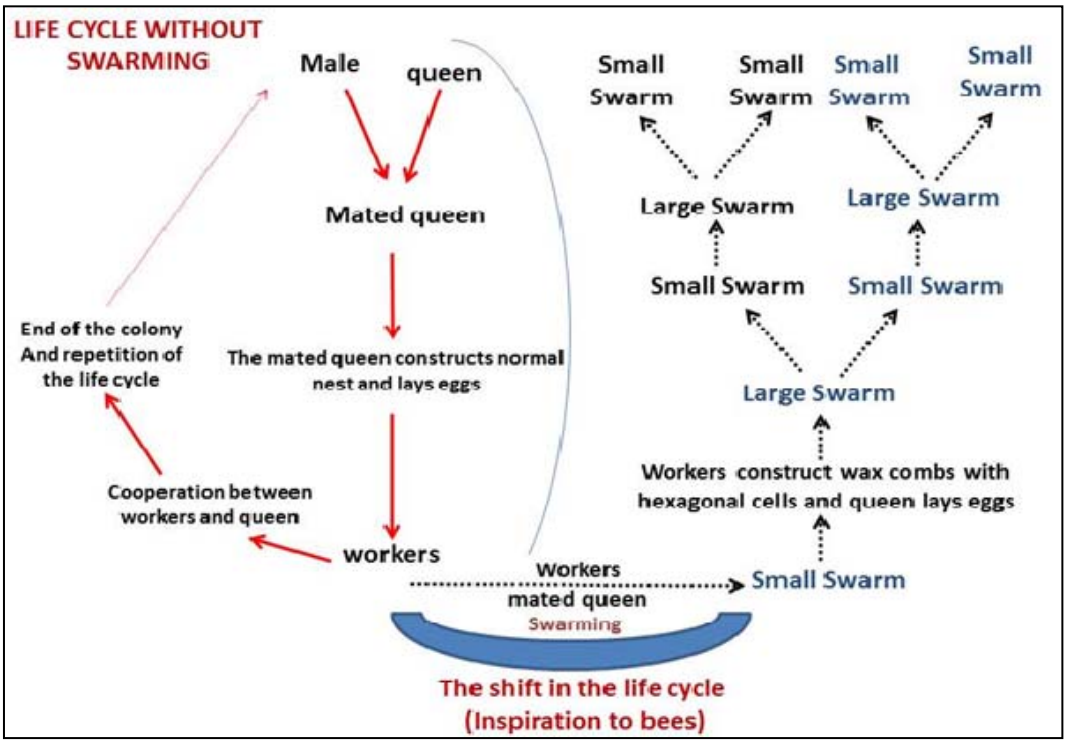

Fig 2: General steps of the suggested scenario for honey bee life.

But why did honey bees shift to reproduce by swarming unlike other social insects? The answer of this question can only be obtained by creationism where a great creator inspired to the bees to swarm to construct nests at different places. The Holy Quran mentioned this at Sura An-Nahl (Bees) page 274. The evolution of the other behaviors, after shifting to reproduce by swarming, can be somewhat explained by the assumptions presented by [12, 13, 14]. But their assumptions cannot explain why the bees decided to reproduce by swarming. Without using swarming as the reproduction method, the colony will not be able to survive for a long period. Moreover, the colony will not be able to store large amount of honey due to the short life period of the colony. Thus, the great shift in honey bee life (swarming) is an inspiration to honey bees, is the keystone of their life origin.

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