Apis mellifera L.

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Introduction

Apis mellifera, also known as the western honey bee (European, as it is native from there), is an insect renowned for its role as one of the most important pollinators on earth. It is indispensable for plant biodiversity and crop quality. They are considered to be one of the most important animals on earth and responsible for about 80% of all flowering plants and 130 fruits and vegetables (Randall 2020).

Its products are some of the oldest used by mankind and have countless amount of benefits varying anywhere from the cosmetic market to the medical. They are responsible for the jobs of countless farmers and the carriers of multiple economies such as that of Ethiopia (Yadeta 2014).

Sadly due to a phenomenon known as the Colony Collapse Disorder (CCD) countless of colonies have been reduced, and in the long run will affect the world as we know it. This disorder consists in the extreme reduction of worker bees in a hive causing the extreme debilitation of the hives often causing the death of them (EPA 2015). It is important for us as humans to strive to protect such important creatures and avoid their extinction at all costs.

In the Ecology chapters we will be going through the basic ecology and history of the *Apis mellifera,* in the Biology chapter we will be going through the basic composition of the hive, the differences between drones, workers and the queen, as well as the life cycle and reproductive biology and physiology. In the propagation and management chapter we will be going over both natural and artificial propagation as well as beekeeping and the management of pests. Finally we will conclude by going over the various products and services that the *Apis mellifera* can provide.

Chapter 2: Ecology

2.1: Affinities

Taxonomy:

- Domain: *Eucariota*
- Kingdom: *Animalia*
- Phylum: *Arthropoda*
- Class: *Insecta*
- Order: *Hymenoptera*
- Family: *Apidae*
- Subfamily:
- Genus: *Apis*
- Species: *A. mellifera*

Apis mellifera is a medium sized bee whose species has been subdivided into at least 20 acknowledged subspecies, consisting of several interbreeding subspecies and outside species like the *Apis mellifera scuttelata* Lepeltier (African Honey bee) (University of Florida 2010). In the United States alone we can find subspecies such as *Apis melifera* Spinola, *Apis mellifera carnica* Polmena, *Appis mellifera mellifera* Linneaus, etc (University of Florida 2010). *Apis mellifera* is a polytypic species that within its subspecies finds itself corresponding to the Rassenkreis. This means that within *Apis mellifera* there is an abundance of subspecies within them (polytypic) that typically exhibit a pattern of geographical displacement. Thanks to research conducted on the morphometric ("the study of shape variation of organs and organisms and it's covariation with other variables" (M. Pares 2017)) taxonomy of the *Apis mellifera,* it is attributed to having 24 well defined subspecies, of which a 3D model in shape of a tripod is used to classify the species in terms of distribution (Kauhausen, Ruttner 1997). Much like the other members of the Hymenoptera group, the Western Honey Bee contains a haplo-diploid sex determination (University of Florida). This means an unfertilized egg develops into drones and a fertilized egg develops into the typical working female bee.

2.2: Fossil Records

"24 different fossil honey bee species or subspecies have been identified. The first fossil species of the genus was described as *A. henshawi* by Cockerell. Although previous fossils had been pro- posed as species of Apis, Cockerell's was the first correctly assigned to the genus" Engel 1998). Of the living *A Mellifera* species only *A Mellifera L* has an identified fossil, product of a fossilized honeycomb in the Malay Peninsula. The most recognized honey bee fossil record, *A Henshawi,* can be found in the Museum of Comparative Zoology, Harvard University. This fossil is particularly well known for its expectable preservation and high quality details that are prominent in the figure (Engel 1998).

A Henshawi fossil record holotype (S. Engel 1998)

[1]

[2]

[3]

Because of an "inadequacy of description" in the *A Mellifera subspecies* there is a need for a more "detailed treatment of the fossil bees. Because of this the Museum of Comparative Zoology have provided new descriptions for the fossilized honey bee "with the attempt to clean up some of the taxonomic difficulties" (S. Engel 1998).

[1] Figure one
[2] Figure 2
[3] Figure 3

Description provided by the Museum of Comparative Zoology on the *A Mellifera Genesis* *(S. Engel 1998)*

Taxon	Epoch	Distribution	References
andreniformis	Holocene	Asia	Smith [33]; Wu and Kuang [39, 40]
armbrusteri	Miocene	Germany	Zeuner [41]; Zeuner and Manning [42]
catanensis**	Miocene	Italy	Roussy [28]
cerana	Holocene	Asia	Fabricius [12]
cuenoti	Oligocene	France	Théobald [36]
dorsata	Holocene	Asia	Fabricius [12]
florea	Holocene	Asia, Arabia, Africa	Fabricius [11]
henshawi	Oligocene	Europe	Cockerell [7]; herein
koschevnikovi	Holocene	Asia	von Buttel-Reepen [4]; Tingek et al. [37]
longtibia	Miocene	China	Zhang [44]
melisuga n. dub.*	Miocene	Italy	Handlirsch [13]; Zeuner and Manning [42]
mellifera	Pleisto-Holocene	Cosmopolitan	Linnaeus [19]; Zeuner and Manning [42]
miocenica	Miocene	China	Hong [15]; Zhang [43, 44]; herein
petrefacta	Miocene	Bohemia	Ríha [27]; herein
vetustus	Oligocene	Germany	herein

* See text for discussion of this dubious species.
** This may not be a valid species.

[4]

[4] Table 1

2.3: Origin

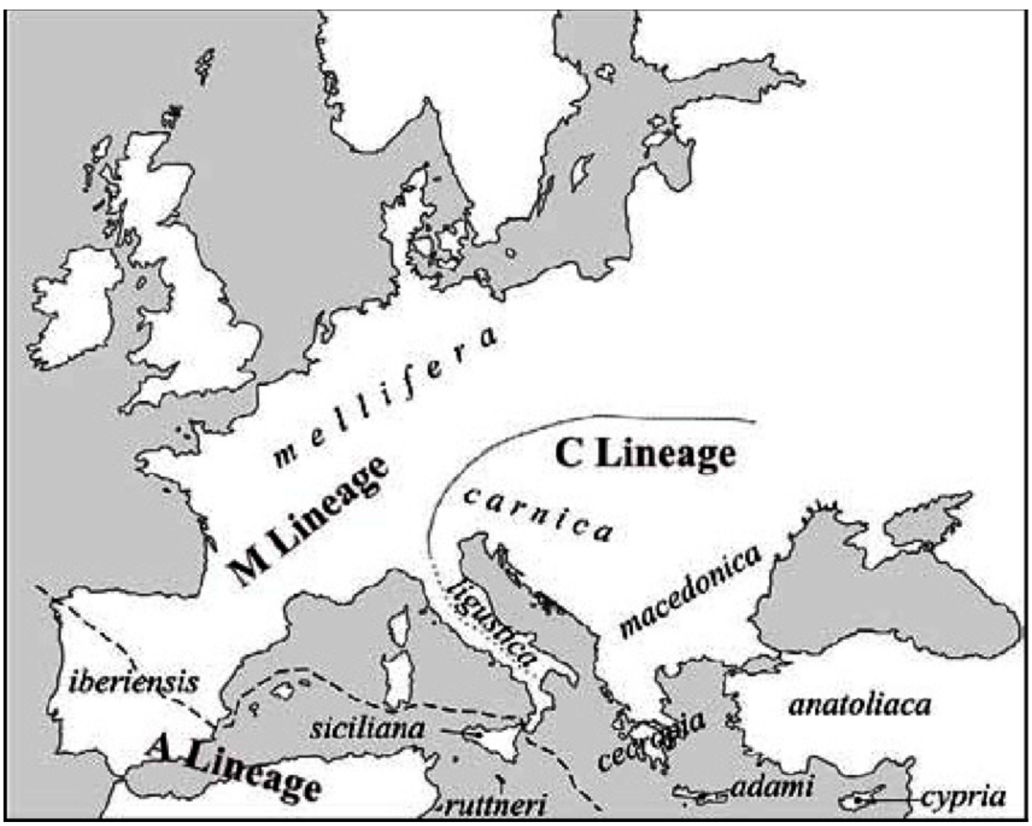
There is great controversy that comes when talking about the origin of *Apis mellifera.* Scientists from all over the world have constantly struggled to pinpoint the exact origins of the western honey bee. A study conducted by the University of Bristol using mitochondrial genomes supports the idea of African or Middle Eastern origin. Apis Mellifera stem from three main evolutionary branches: branch M (Eastern European), branch A (African) and branch C (Southeastern European). It is believed that branch M could have originated in Africa due to morphological clines found crossing from the equator to The Polar circle (Frank et al, 2017). An extreme divergence in lineage was found between branch A and M but found contact between both lineages in the Iberian Peninsula meaning a possible Africanization of the M lineage in a very small scale.

While it is difficult to pinpoint exactly, it is believed that the origin of *Apis Mellifera* started 270 million years ago with what is known as the *Hymenoptera evolve.*

2.4: Present distribution

The Western or European honey bee, as the name suggests, is native to the continent of Europe yet, thanks to the many economical and ecological benefits of the honey bee they have managed to expand beyond its natural range. Currently we can find *Apis mellifera* in every single continent of the globe excluding Antarctica (University of Florida 2010). When it comes to the distribution of honey bees, there is a deep complexity lying within the surface. While all *Apis mellifera* may stem from Europe, the distribution of the species makes for a variety of alterations that make each subspecies unique.

***Apis mellifera* lineage origin distribution (Rua 2018)**



[5]

[5] Map 1

Originating from Eastern Europe, Asia and Africa, it wasn't until the 17th century that human introduction of this species began. Currently they can be found around the world in all continents (Handon, Blankenship 2007).

Biogeographic Regions: nearctic (introduced), palearctic (native), oriental (introduced), ethiopian (native), neotropical (introduced), australian (introduced)

Other Geographic Terms: cosmopolitan

2.5: Environmental factors

Apis Mellifera prefer places with an abundance of ready available food and water, making meadows, open woods and gardens some of their preferred choices. They depend on enclosed cavities to make their hives due to their high susceptibility to other predators that attract the bees or consume the food or wax stored in the hives (Hammond and Blankenship 2009). The main invertebrate predators of the *Apis Mellifera* consist of both crab and orb weaver spiders and *Philanthus* and *Vespidae* wasps, *Vespidae* being one of its most aggressive.

Birds as well as other vertebrae animals possess an important threat for the colonies. The *Meropidae* are particularly aggressive in Africa and Easter Europe and Tyrannidae and

Muscicapidae are a present threat all around the world. The main vertebrae predators of the *Apis Mellifera* are mammals such as bears and honey badgers.

Habitat Regions: temperate, tropical and terrestrial

Terrestrial Biomes: desert or dune savanna or grassland chaparral forest

Wetlands: swamp

Other Habitat Features: urban suburban agricultural

(Hammond and Blankenship 2009)

The speed of “subsequent development” of the larva is highly affected by temperature. Ideally at this stage of development the temperature should be between 33 and 36 fahrenheit. Bees are highly sensitive to weather meaning they won't forage in extrémame weather conditions, as they can't fly in temperatures under 10 Celsius (Hammond and Blankenship 2009). Most pollen recollection happens during warm and calm weather and the moment a rapid shift in the light intensity occurs the foragers return to the hive and the pollen collection stops (the nectar collection will continue in light rain) (Hammond and Blankenship 2009).

Chapter 3: Biology

3.1: Hive composition

A typical hive is composed of three main bee types. The drone (male), the worker (non reproductive female) and queen (reproductive female). The drone and the worker have different roles in the colony leading to a variation in physiology, morphology and behavior (Hrassnigg, Crailsheim 2005).

3.2: Drone

The drone is the male bee of the hive. They are born from unfertilized eggs laid by the queen or in some cases other worker bees. Their main job is to maintain the colony´s DNA and spread it on to other hives (Hrassnigg, Crailsheim 2005).

3.3: Worker

The workers are one of the two casts of females that, in comparison to the queen , are sterile workers and range between 10 to 15 mm long. Workers tend to have longer wings than drones despite being smaller in size.

3.4: Queen

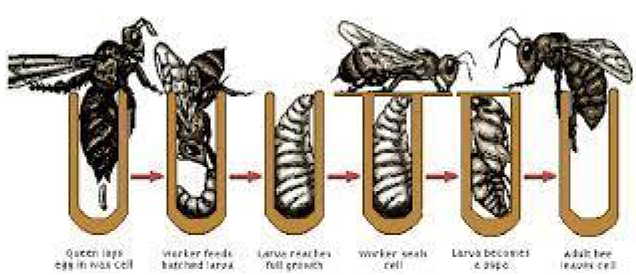
The queen is the other part of the female cast in the hive. Their main purpose is to reproduce and maintain the population of the hive. It is the only female with the ability of mating and the hive's whole purpose is focused on the protection and reproductive habits of the queen.

3.5: Chromosome Complement

Apis Mellifera have what is known as a haploid diploid sex system, meaning the male (drones), come from unfertalized eggs (haploid), and the female come from a fertilized egg (diploid). The males have half as many chromosomes as the female. The drones have 16 chromosomes while workers have 32 chromosomes. This results in sisters sharing a closer DNA than mothers to their daughters. Sisters can share up to 75% of their genes with each other whereas a typical mammal will only share 50% (Chadwick, Et Al 2016).

When a drone is born It receives 100% of his genes from the queen as a direct result from his lack of father. A worker bee will receive 100% of the fathers genes and only 50% of the queens, making the drones indispensable for the maintenance of the lineage (Chadwick, Et Al 2016).

3.6: Life Cycle



[6]

[6] Figure 6 (Desalegen)

It is said that a honey bee colony should be referred to as a super organism in which every individual works together to become better than the sum of its parts. Due to this reason a honey bee's reproduction seems akin to that of the developing muscles.

Reproduction begins with the queen bee laying the egg. This process usually commences in the spring and continues throughout the season. After the nautical laying of the egg, different worker bees begin to take care of the larvae as it begins evolving, providing it with the necessary food and help. When the larvae is sufficiently grown the worker bee will cover up the cell with the larvae inside. This is known as the closed larvae. After the cell is sealed the larvae will continue its development until fully formed and an adult bee will sprout.

Apis Mellifera are holometabolous meaning they have 4 main stages in their life cycle: egg, larva, pupa and adult. Eggs typically hatch between 28 and 144 hours varying on the temperature of the hive. As the larva emerges it is fed and groomed by other adult workers. The food they receive will determine whether the larva will become a worker or a queen, the queen is fed royal jelly and the worker receives regular food. The growth period of the larva varies depending on whether they are workers (4-5 days), queens (6 days) and males (6-7 days). It is after this period that the cell in which the larva is located gets sealed by another worker and the larva transforms into a pupa in which they will undergo a metamorphosis (7-8 days queens, 12 days worker, 14-15 days males). When the process is complete they will chew themselves out of the cell and will begin their adult lives (Adjare, 1990; Sammataro and Avitabile, 1998).

3.7: Reproductive Biology

Apis Mellifera have as stated before a *Haploid Diploid* reproduction system. The drones (males) have a *Haploid* system, meaning they stem from unfertilized eggs laid by the queen. In the absence of a queen, worker bees may lay unfertilized drone eggs, these are known as the laying worker bees as a way to preserve and spread the genetics of the species but ultimately leading to its demise (Deeley 2014).

3.8: Physiology

Due to the varied roles of both the drone and worker bees, variation in the physiology of the bees can be seen in both types. The main physiological differences can be seen in the diet, metabolism and digestion of the bees (Hrassnigg, Crailshem 2005).

In the larvae stage, drones have different sugar and protein requirements than their female counterparts and throughout each life stage differ in their percentages of glycogen, lipids and proteins (Hrassnigg, Crailshem 2005).

Chapter 4: Propagation and Management

4.1: Propagation

4.1.1: Natural Regeneration

In a hive only the queen mate and lay eggs and typically there is only one reproductive bee per hive. The majority of workers are sterile or only able to produce drones (unfertilized eggs). *A. Malifera* are polyandrous and eusocial insects (having an advanced level of social organization), meaning that the queen has multiple mates (Michael Mikát Et Al 2017) . During periods with suitable conditions, drones will leave the hive and assemble in drone assembly areas in which a virgin female queen will fly through and attract the drones with their pheromones. The males will pursue the queen and form clusters around her in an attempt to mate. Those who are successful in the process will die within a few hours (Tarpy and Page Jr., 2000).

Breeding interval Colonies typically swarm once or twice a year, usually at the beginning of the season that provides the most nectar.	**Breeding season** Late spring until the winter months	**Range eggs per season** 60,000 to 80,000
Average gestation period 3 days	**Range age at sexual or reproductive maturity (female)** 15 to 17 days	**Average age at sexual or reproductive maturity (male)** 24 days

[7]

Numeric data on the reproduction of A. Mellifera (Adjare, 1990)

[7] Table 2

Queens can mate with drones from either inside her own hive or other foreighn hives. The queen uses directional flights a couple of days before mating in order to determine the best space for her to mate. The queen will only do this process four times in her lifetime and never matre again (Adjare, 1990; Sammataro and Avitabile, 1998).

All activities are centered on the reproductive behaviors and survival of the queen. A fertile queen can lay up 200,000 eggs per day. A queen can decide whether to lay fertilized or unfertilized eggs depending on the colony's need. If a colony is strong enough it will begin the reproduction of multiple queens and once the new queens hatch the original queen will “swarm”. Meaning it will leave the hive with a number of worker bees and swarm in a nearby space as they find a space to create a new colony. The remaining bees of the original hive will fight for survival and the remaining queen will assume her role as the new queen (Tarpy and Page Jr., 2000).

If a colony is left queenless for an extended period of time some worker bees will begin laying unfertilized eggs (drones) (Tarpy and Page Jr., 2000).

4.1.2: Artificial Propagation:

The process of artificial insemination in *A. Mellifera* colonies was introduced in the early 20th century and has since become an integral part of breeding and research programs of the species. Recently research has focused mostly on semen storage and handling, and an advancement in molecular biology have helped our understanding of the hive's reproductive biology (Thomas L.Gillard and Benjamin P.Oldroyd, 2020).

One of the methods used is that of *In Vitro*, in which the fecundation process does not go on naturally in the queen but instead happens in a test tube or petri dish. This has become increasingly important in understanding the pathology and toxicology of the bees. The in vitro method can be used for one of two ways, either to generate a worker or queen that can be successfully introduced into the hive or as a way of testing different pathogens or compounds (Karl Crailsheim Et Al, 2015).

Despites the importance or the efforts that have been made in the breeding of *A. Mellifera,* it is hard to obtain satisfying results and new and different tactics have come about to help. Such a tactic is known as controlled mating, in which the maternal counterpart is controlled and the drones are left at random. This increases the chances for the successful breeding of the bees is between 47 and 99% (Manuel Plate Et Al, 2019).

4.2: Management

4.2.1: Beekeeping

Beekeeping, in comparison to other animal related agricultural affairs, depends on taking care of the bees instead of simply controlling or hurting them. The first interaction between humans and honey bees was in the form of “honey hunting” in which foragers and hunters seek’d honey from wild colonies. This approach seemed fruitless due to the honey bees' intricate defense system. The earliest documentation of hive keeping dates back to the Old Kingdom of Egypt and served as inspiration for the modern portable beehives used by beekeepers. Yet modern beekeeping has shied away from the ancient practices and has therefore taken its toll on the bees (Gupta et al. 2014).

The act of beekeeping is necessary for securing food production, health and environmental protection and even the reduction of poverty and most of all plant pollination. In recent years new biotic and abiotic threats have risen that have put in danger the act of beekeeping. Both climatic and human induced factors have contributed to the sharp decline of honey bee populations (Wakagari, Yigezu 2020).

The correct management of bees is completely dependent on the hands of the beekeepers. These practices may vary depending on the beekeeper in two key ways: low or high intervention in regards to the manipulation being used in the hive. These manipulations consist of the use of chemicals, supplemental feeding and over all hive manipulation from the direct hand of the beekeepers. Test's made by Pennsylvania State University concluded that the approach beekeepers use to tend to their bees varies in the philosophy they possess, whether that maybe more towards the use of chemicals or others a more classic approach. This philosophy also indicates another important factor in the development of a beekeeper's operation. The overall goals of the beekeeper will indicate the size of the operation run and the type of management used, especially in the use of chemicals (Underwood et al, 2019).

4.2.2: Virus Control

The Varroa mite also known as the Varroa distructor is a parasitic mite that feeds off and attacks *Apis Mellifera* colonies. This infestation has become a rising concern for beekeepers in the last 50 years. To control this pest as well as others various sampling methods have been generated to calculate infestation levels as well as different acaricides (Roth et al. 2020). The use of chemicals in the hive has been a highly controversial alternative to controlling pest infestations and viruses that can affect the colony (Underwood et al, 2019).

Chapter 5: Products and Marketing

5.1: Products:

5.1.1: Honey

The Codex Alimentarius defines honey as the “natural sweet substance” produced by honey bees using different parts of plants and different substances produced by [the bees] themselves. When these are collected bees will take the honey and store it in the honeycomb to dehydrate and store so that the honey will ripen and mature (Garcia 2018).

Honey is a healthy product composed of an estimate of 200 substances, the main of which are sugars. The second largest component is water which gives it most of the physical properties we use to characterize honey. It also has multiple additional substances “such as proteins and enzymes, amino acids, organic acids, vitamins, minerals, phenolic and volatile compounds” that give it its healthy aspect (Garcia 2018).

Honey is one of the most well known bee products in the market. Considered the third “favorite food” by Pharmacopoeias Fraud DataBase, there is a high demand for honey. This has opened the door to adulturred honey as a way to compete with the everising demand. In order for honey to be considered pure it must have no “food auditions' ' or “constituent removed” (Garcia 2018).

5.1.2: Propolis

Propolis is a "resinous product" collected from different plant species by bees (Irigoti et al 2021). These compounds contain antibacterial, antioxidant and anti-inflammatory properties that make propolis ideal as an active food ingredient as well as other uses in the medical field (Irigoti et al 2021; Castaldo & Capasso 2002).

Propolis has managed to maintain its popularity throughout time thanks to "flavonoids and phenolic acids and their esters" that have "multiple effects on bacteria, fungi and viruses". It has also been linked to a reduction of blood pressure and cholesterol levels (Castaldo & Capasso 2002).

5.1.3: Beeswax

Beeswax is one of the most recognized and celebrated bee produced products. It is one of the oldest products used by humankind and is used in multiple fields, such as the cosmetic industry, pharmaceutical, gastronomical and engineering fields. It is considered to be one of the most valuable bee products thanks to its unique characteristics that make it applicable to almost any line of work. The biggest market for beeswax is found in the cosmetic and pharmaceutical business (Yadeta 2014).

Beeswax is produced in one of the four wax glands of the *Apis mellifera,* a process that is extremely costly energywise and uses mostly pollen and nectar (Yadeta 2014).

5.1.4: Royal Jelly

Royal jelly is the food used by young worker bees in order to feed the young larvae of future queens.

Royal Jelly is a highly studied product thanks to its bioactivities (antimicrobial, antioxidant, anti-aging and immunomodulatory) and general tonic actions against "laboratory animals, microbial organisms, farm animals, and clinical trials" (Ahmad et al. 2020).

It is one of the most valued natural products and is often seen being used in cosmetics, traditional medicine and other "health food[s]" (Ahmad et al. 2020). It is used to supplement a high variety of diseases such as "cancer, diabetes, cardiovascular, Alzheimer's disease," among others (Ahmad et al. 2020). It finds most of its success in the pharmaceutical and health industry thanks to its "main bioactive compounds" (Ahmad et al. 2020).

5.2: Services

5.2.1: Migratory Beekeeping

Migratory beekeeping is the line of work in which beekeepers take their apiaries across the country in order to complete the service of pollinating crops. The main objective of these migratory beekeepers is the pollination of crops, something that is crucial for the growing multiple foods we consume on a daily basis (Holly 2020).

In order for the beekeepers to successfully translate hundreds of colonies across states and countries, they must depend on the use of pallets and flatbed trucks to transport their hives.

Most beekeepers plan their roots by following the regional growing cycles, in which they predict the time period in which the certain plants grow (Holly 2020).

Despite the economical importance of migratory beekeeping it has its downside. The most important of which is known as MBRP (Migratory Beekeeping Rooting Problem). This problem focuses on the competition beekeepers have to face in order to find nectar and pollen sources. The overlapping of routes as well as over populations of beekeepers in the area might lead to the decline of many colonies (Ma et al. 2020). Other problems faced by migratory beekeeping is the exposure to un-expected pesticides in the crops, which leads to the loss of a substantial amount of colonies each year and is one of the main contributors to what is known as the Colony Collapse Disorder (Chadwick, Et Al 2016).

5.2.2: Apiturism

Apitourism is a type of tourism that connects beekeeping with bee products in the "ecological, food and medicinal aspects" (Wos 2014). There is a high range of activities connected with apiturism such as "visits in apiaries, open-air museums and bee museums where tourists have the opportunity to observe a beekeeper's work, a method of making honey, its properties and specifics, to find out about other bee products, to watch how bee colony live, to recognize ecological correlation between a man and bees," alongside many others (Wos 2014). This is a great way to connect tourism with rural communities and one of the most sustainable forms to do so (Wos 2014).

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