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| **Mutualism and Coevolution:**  **Bats and Agave** |  |

## Objectives

Students completing this module will be able to:

* Explain the role of pollinators in the life history of angiosperms.
* Define coevolution and identify selection pressures that exist between pollinators and the plants they pollinate.
* Predict pollinator/plant pairs based on morphological traits.
* Collect data from a digitized natural history collection.
* Analyze spatial co-occurrence data for pollinators and the plants they pollinate.
* Discuss how data from natural history collections can be used to investigate scientific questions with large temporal or spatial scales.

**Introduction**

**Mutualism** is a type of interspecific interaction where both species benefit from the interaction with the other. The relationship between pollinators and the plants they pollinate is an excellent example of this type of interaction. The plants benefit by having their male gametes (precursor cells are contained within the pollen grain) spread to other individuals, allowing for reproduction and increased genetic diversity. The pollinators typically benefit by eating the nectar produced by flowers specifically to attract them to the plant to allow pollination.

Flowers are also modified in a variety of other ways in order to attract pollinators. Some cues are visual, like flower color and pattern. Some flowers use scents to attract pollinators. The “match” between the morphologies of the flower and its pollinator are also important to facilitate pollen transfer.

Any flower trait that increases pollen transfer should increase a plant’s fitness and will be favored by natural selection. Likewise, any trait that the pollinator possesses that increases its feeding efficiency on the nectar can increase the pollinator's fitness. The plant and its pollinator act as selection pressures on each other. This reciprocal selection is called **coevolution**.

In this module, you will be investigating the mutualistic relationship and coevolution between bats and the agave plants they feed on and pollinate.

**Activity 1: Coevolution of Agave and Bat Morphology**

The suite of characters exhibited by a plant that is associated with a specific pollination vector is called a **pollination syndrome**. Often you can infer the pollinator of a plant based on its floral morphology. Different pollinators have different visual capabilities, are attracted by different odors, are active at different times of day, and have different nutritional needs. The coevolution of plants and their pollinators has led to flowers with specific characteristics that attract their pollinator and facilitate pollination.

Over 500 species of angiosperms rely on bats as either their primary or only pollinator. Bats are nocturnal flying mammals. The most common species in North America have a body length (nose to tail) of 2-3 inches, a wingspan of approximately 10 inches, and a mass of between 15 – 25 grams. Many species are completely color-blind, but even for those with color vision, being active at night limits the importance of color for their foraging. They have a keen sense of smell and use this information to locate food resources, favoring the musty odors produced by warm, moist organic matter.

1. Based on this information, fill in the table below with your predictions on the characteristics of the flowers of bat-pollinated plants.

**Predicted Flower Characteristics of Bat-Pollinated Plants**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Color** | **Scent** | **Flowering time** | **Shape** | **Reward**  **(nectar/pollen)** |
|  |  |  |  |  |

1. Visit the website linked below (or do a web search) to check your predictions. Fill in the table below with the characteristics of the flowers of bat-pollinated plants.

US Forest Service: <https://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml>

**Characteristics of Bat-Pollinated Plants**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Color** | **Scent** | **Flowering time** | **Shape** | **Reward**  **(nectar/pollen)** |
|  |  |  |  |  |

Tequila is made from the plant *Agave tequilana*, a large plant with a blue green coloration and spiky fleshy leaves arising in a rosette. Agave can take 5 years or more to flower. When *A. tequilana* flowers, it produces a single flowering stalk that can be up to 15 feet high and has a large inflorescence. Once pollinated, the plant can produce thousands of seeds and then it dies. The flower morphology is shown below.

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| /Users/linto1dl/Dropbox/1 - Teaching/BIO 111/saguaro6.jpg | /Users/linto1dl/Desktop/5533y-bloom.JPG |

The Mexican long-nosed bat (*Leptonycteris nivalis*) and the lesser long-nosed bat (*Leptonycteris curasoae*) are the primary pollinators of [*Agave tequilana*](http://books.google.com/books/about/Agaves_of_Continental_North_America.html?id=SCqGyWNpRHwC)*.* These species are shown below.

|  |  |
| --- | --- |
| *Leptonycteris nivalis* | mage result for leptonycteris curasoae  *Leptonycteris curasoae* |

1. What characteristics of the bats allow them to successfully feed on and pollinate *Agave tequilana*?

Other species of bats have different food sources and require different morphological adaptations to access those food sources. Vampire bats, for example, feed on the blood of animals. The common vampire bat (*Desmodus rotundus*) thrives in agricultural areas and feeds on livestock, such as cows, pigs, and chickens. Two other species of vampire bat (Diaemus youngi and *Diphylla ecuadata*) live in forests and fed on birds, reptiles, and other forest animals.

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| *vampire-bat-desmodus-rotundus-portrait-michael-patricia-fogden.jpg*  *Desmodus rotundus*  Common Vampire Bat | mage result for diaemus youngi teeth  *Diaemus youngi*  White-winged Vampire Bat | *diphylla-ecaudata-hairy-legged-vampire-bat-DTF16N.jpg*  *Diphylla ecaudata*  Hairy-Legged Vampire Bat |

1. What morphological adaptations do you think help these sanguivorous (blood-eating) species obtain their food supply?

**Activity 2: Agave and Bat Geographic Distribution**

Species involved in an interspecific interaction with each other must exist in the same geographic location for at least part of their life history. This means that changes in the distribution of one of the species can have an impact on the distribution of the other. In the next set of exercises, you will be using digitized natural history collections to estimate the geographic ranges of different species and discuss how this relates to their potential interspecific interactions.

*Agave tequilana* is dependent on two bat species (*Leptonycteris nivalis* and *Leptonycteris curasoae*) for its reproduction.However, the bats are not completely dependent on a specific species of plant for their nutritional needs. The bats that pollinate [*Agave tequilana*](http://books.google.com/books/about/Agaves_of_Continental_North_America.html?id=SCqGyWNpRHwC) migrate every spring over 1000 miles moving from Mexico into the southwestern US and can also feed from (and in the process pollinate) several other species of *Agave* as well as some cactus species.

# Based on this information, how would you predict the distribution of the bat species to compare to the distribution of the plant species? Pick from one of the examples below:

* Distribution of *Agave tequilana* and the bat pollinators will be the same.
* Distribution of *Agave tequilana* will be more extensive than the bat pollinators
* Distribution of the bat pollinators would be more extensive than the *Agave tequilana.*

Explain your choice:

**iDigBio (Integrated Digitized Biocollections)** is a data aggregator for digitized natural history collection data. All data in this portal are linked to a specimen in a natural history collection and can be independently verified.

1. Go to the iDigBio portal ([www.idigbio.org/portal](http://www.idigbio.org/portal)) and input these three species. [if you are not familiar with this resource, your instructor will show you how to search the portal; a set of instructions is available on the course website]. Take a screen shot from each map and paste it in the space provided below. Write down how many records were found in iDigBio for each species.

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| --- | --- |
| # of Records:  *Agave tequilana* | |
| # of Records:  *Leptonycteris nivalis* | # of Records:  *Leptonycteris curasoae* |

**GBIF (Global Biodiversity Information Facility)** portal is a data aggregator for all types of biodiversity occurrence data. GBIF includes observation-only data (not linked to a preserved specimen) in addition to specimen-based natural history collection data. Observation records can come from sources such as citizen science data collected by volunteers (e.g., Christmas Bird Counts), as well as observations made by researchers in ecological field studies.

1. Go to the GBIF portal ([www.gbif.org](http://www.gbif.org)) and input these same three species. Take a screen shot from each map and paste it in the space provided below. Write down how many records were found in GBIF for each species.

|  |  |
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| # of Records:  *Agave tequilana* | |
| # of Records:  *Leptonycteris nivalis* | # of Records:  *Leptonycteris curasoae* |

1. How does the distribution of individual species differ when using data from the different portals, GBIF and iDigBio? Why would this be the case?
2. What did you observe for distribution of *Agave tequilana* relative to the bat pollinators?

* Distribution of *Agave tequilana* and the bat pollinators will be the same.
* Distribution of *Agave tequilana* will be more extensive than the bat pollinators
* Distribution of the bat pollinators would be more extensive than the *Agave tequilana.*

How would you explain the observed distributions?

1. What evidence from the maps could you use to support the conclusion that these two bat species do not feed exclusively on *Agave tequilana* nectar?

When the Mexican long-nosed Bat and the lesser long-nosed bat migrate, they are dependent on the flowering cactus and agave plants for the sugar and protein-rich nectar along the route. The bats are not species specific in their nectar foraging but instead can feed on several types of paniculate agaves (e.g., *Agave angustifolia* and *Agave tequilana*) and columnar cacti (e.g., *Carnegiea gigantea*).

1. Go to the GBIF portal and input these three species. Take a screen shot (limit to North, Central, and South America) from each map and paste it in the space provided below. Write down how many records were found in GBIF for each species.

|  |  |
| --- | --- |
| # of Records:  *Agave tequilana* | |
| # of Records:  *Agave angustifolia* | # of Records:  *Carnegiea gigantea* |

**The lesser long-nosed bat (***Leptonycteris curasoae***) is one of only** three species of bat nectarivores that have substantial long-distance migration (up to 1800 km). Migrating from central Mexico, the northernmost roosting sites are just across the border into the southwestern part of the US. Lesser long-nosed bats form spring maternity roosts in northern Mexico and the southern US. Southern migration occurs in late summer and early fall. From October to December, males and females congregate in southern/central Mexico to mate.

1. Which of the three plant species do you predict are a major food source for the lesser long-nosed bats in May? What is your evidence.
2. Which of the three plant species do you predict are a major food source for the lesser long-nosed bats in December? What is your evidence.

**Activity 3: The Trouble with Vampire Bats**

Humans have a long history of fear associated with bats. Vampire bats have a particularly bad reputation, as they feed on blood from cattle and sheep sleeping at night and can carry disease and promote infection that can spread to other livestock and even humans. Ranchers use a variety of tactics to kill the vampire bats. The kill practices are often targeted at roosts in caves and can wipe out most of the bats in a cave.

1. Go to the GBIF and input the three species of vampire bats listed in the table below. Take a screen shot (limit to North, Central, and South America) from each map and paste it in the space provided below. Write down how many records were found in GBIF for each species.

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| --- | --- |
| # of Records:  *Desmodus rotundus* | |
| # of Records:  *Diphylla ecaudata* | # of Records:  *Diaemus youngi* |

1. Look at the distribution of the three species of vampire bats. How does that compare to the distribution of Mexican and lesser long-nosed bats?
2. Based on the species distributions of all five bat species, does the cave-wide mass extermination of vampire bats appear to pose a risk to Mexican and lesser long-nosed bats? Explain your answer.
3. Brainstorm some ideas about what might be done to address this problem.

**Assessment**

*Ophrys sphegodes, commonly known as the early spider-orchid* is pollinated by the solitary bee *Andrena nigroaenea*. These orchids attact pollinators by sexual deception. They produce the sex pheromones of female bees and also provide visual and tactile cues, attracting the males for “mating”. During pseudocopulation, the pollinia are transferred to the male bee’s head and pollen can be transferred to the next flower visited. The flowers don’t provide nectar to the bees as a reward, so there is a net energy loss to the bees who are fooled by the deception.

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| Macintosh HD:private:var:folders:TL:TLeomGpAH24WJTp1NCqapk+++TM:-Tmp-:TemporaryItems:Early-spider-orchid-flower-Dorset.jpg  *Ophrys sphegodes* | *Andrena nigroaenea*  Source: <https://www.flickr.com/photos/>  gails\_pictures/ [Gail Hampshire] |

1. Is the relationship between *Ophrys sphegodes* and *Andrena nigroaenea* a mutualistic interaction? Explain your answer.
2. Explain the selection pressures that each species exerts on the other and describe the adaptations that have resulted.
3. Go to [www.gbif.org](http://www.gbif.org). Search for *Ophrys sphegodes*. Take a screen shot of the distribution and paste it below. Record the number of specimens.
4. Go to [www.gbif.org](http://www.gbif.org). Search for *Andrena nigroaenea*. Take a screen shot of the distribution and paste it below. Record the number of specimens.

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| --- | --- |
| # of Records:  *Ophrys sphegodes* | # of Records:  *Andrena nigroaenea* |

1. How do the distributions compare?
2. Is there any evidence from the maps that indicates that *Ophrys sphegodes* may be pollinated by other species besides *Andrena nigroaenea*? If so, explain your evidence.

**References and Resources**

Jacquemyn H, Hutchings MJ. 2015. Biological flora of the British Isles: *Ophrys sphegodes*. *Journal of Ecology* 103, 1680-1696.

Robbirt KM, Roberts DL, Hutchings MJ, Davy AJ. 2014. Potential disruption of pollination in a sexually deceptive orchid by climatic change. *Current Biology* 24, 2485-2489.

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