




---

---

---

---

---

---

---

---

### Animal pollination and rewards

- ~88% flowering plants are animal pollinated
- Nectar is most common reward to attract pollinators
- Species in more than 166 plant families lack nectaries
- Pollen, scents, oils...

Ollerton et al. (2011)

---

---

---

---

---

---

---

---

### Using pollen to attract pollinators

- Many plants provided pollen as main/only reward
- Dual pollen fates in pollen-rewarding flowers
  - Pollinator food (attraction)
  - Carrier of gametes (fertilization)
- How to use pollen to attract pollinators while preserving enough grains for fertilization?

---

---

---

---

---

---

---

---

## Maximising plant reproductive success

1. Use pollen otherwise lost from pollination
2. Many, small pollen grains
3. Limit pollen access (poricidal anthers)
4. Specialization of pollen function (division of labour)

Vallejo-Martin et al. 2009

---

---

---

---

---

---

---

## Why do bees use vibrations to remove pollen?

- Bees use vibrations to collect pollen from flowers with varied morphologies
- Vibrations facilitate pollen grain collection

Buchman (1985)



---

---

---

---

---

---

---

## Why do bees use vibrations to remove pollen?

### Unlocking mechanism

- Some anther types do not release pollen spontaneously



---

---

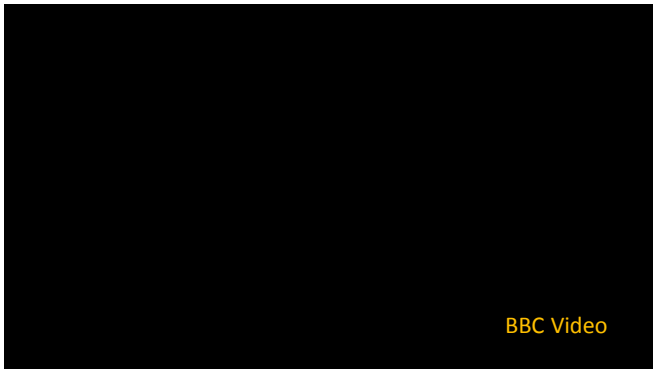
---

---

---

---

---



---

---

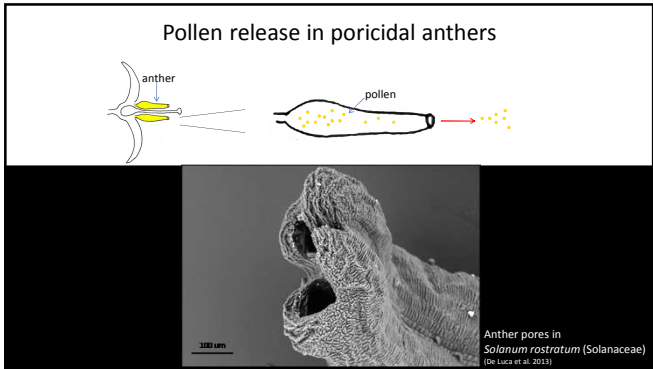
---

---

---

---

---



---

---

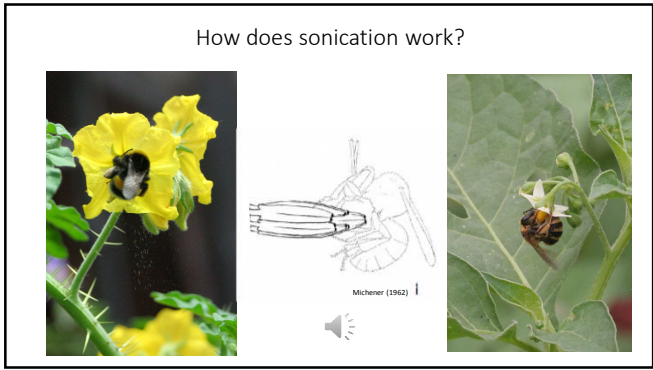
---

---

---

---

---



---

---

---

---

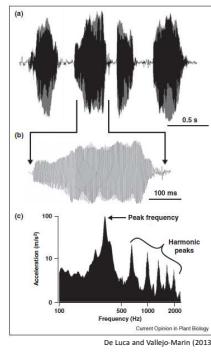
---

---

---

## Anatomy of a bee's buzz

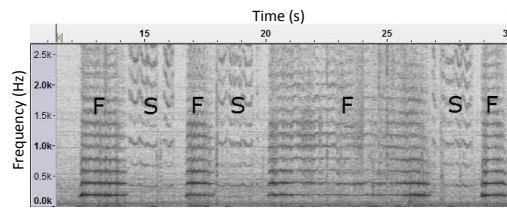
- Duration
- Acceleration/amplitude/intensity
- Frequency (cycles per second, Hz)



De Luca and Vallejo-Martin (2013)

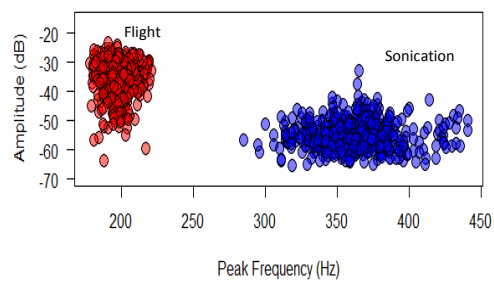
## Not all buzzes are the same

- Comparison of flight vs. feeding sonication



Frequency spectrogram during bumblebee visitation to *Solanum rostratum*

Morgan et al. (2016)

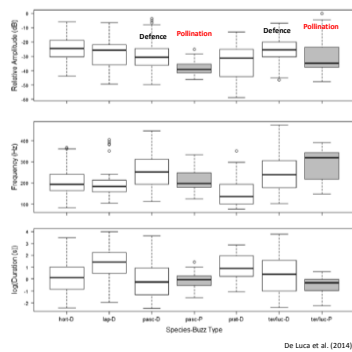


## Comparison of defensive vs. feeding sonifications



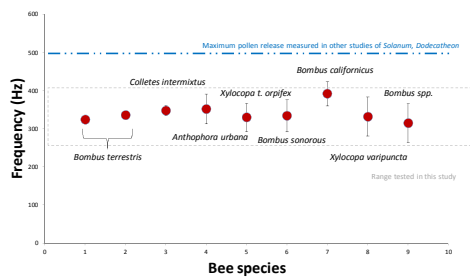
Darryl Cox, Paul de Luca

- Wild British bumblebees (*Bombus* spp.)
- Defensive buzzes elicited experimentally
- Pollination buzzes recorded when visiting *S. rostratum*
- Sonifications registered with audiorecorder



De Luca et al. (2014)

## Dominant vibrations produced by some bees

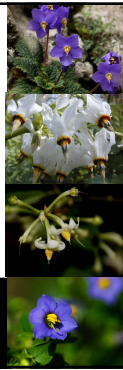
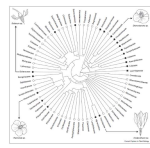


De Luca et al. unpublished, Buchmann et al 1977, King and Buchmann 1996, Harder and Barclay 1994.

## Floral adaptations in buzz-pollinated plants

# The "Solanum" flower

- Convergence in floral morphology across disparate plant families
- Myrsinaceae, Boraginaceae, Cyanastraceae, Liliaceae, Gentianaceae, Sterculiaceae, Gesneriaceae.




---

---

---

---

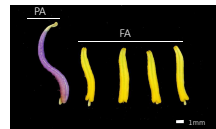
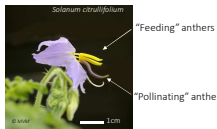
---

---

---

---

## Floral adaptations in buzz-pollinated plants



"Thus, it may be safely assumed that... fertilisation is almost exclusively effected by the pollen of the longer stamens, whilst the shorter stamens serve only to attract pollen-eating insects."

F. Müller (1883). Nature, p 364




---

---

---

---

---

---

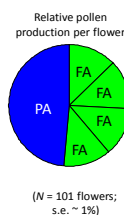
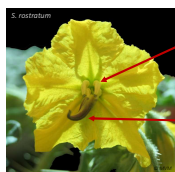
---

---

## Testing the division of labour hypothesis

The division of labour hypothesis requires:

- 1) FA are more attractive to pollinators than PA
- 2) PA are more effective at fertilizing ovules than FA




---

---

---

---

---

---

---

---

## Pollinator behavior in experimental arrays

### Methods:

- *Solanum rostratum* arrays
- Free-foraging bumble bees (*Bombus impatiens*)
- **Block access to pollen**
- Three treatments:
  - FA only (PA glued shut)
  - PA only (FA glued shut)
  - Control (sham glue)
- ~30 flower visits per trial; 22 trials



- Number and length of visits
- On-flower behavior

---

---

---

---

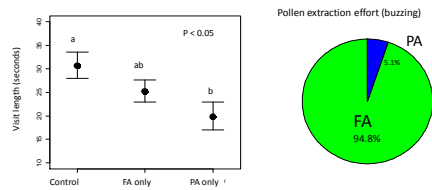
---

---

---

---

## Pollinator attraction



- Plants spend a disproportionate amount of time manipulating FA

---

---

---

---

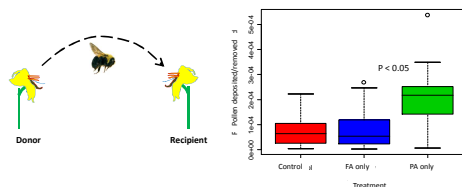
---

---

---

---

## Pollen export



- Pollen from the PA is disproportionately more likely to reach other stigmas

---

---

---

---

---

---

---

---

## Experimental support for division of labour within flowers



*Solanum rostratum*

- PA pollen is 3.7 times more likely to reach stigmas
- Blocking FA reduces visit length

Vallejo-Marin et al. (2009), JEB.

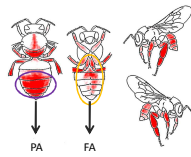


*Melastoma malabatricum*

- 80% of pollen on stigmas is from PA
- Removal of FA reduces visitation

Luo et al. (2009), Func. Ecol.

## Pollen placement in heterantherous *Solanum*



- Pollen is placed and picked up in particular regions of the pollinator's body

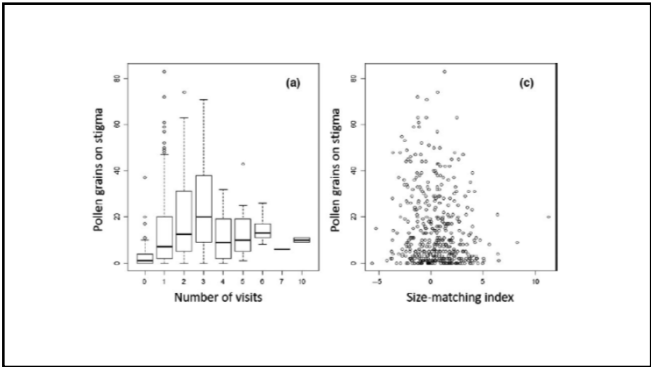
## Lock-and-key matching between flowers and pollinators



**Research question:** Does the morphological fit between flowers and pollinators affect pollen deposition? An experimental test in a *Phlox* pollinated species with another dyschiridopsis

■ *Phlox subulata* / *Phlox* ■ *Phlox subulata* / *Phlox*






---

---

---

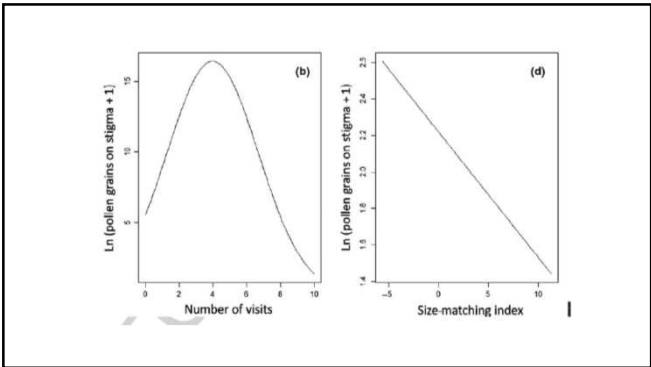
---

---

---

---

---




---

---

---

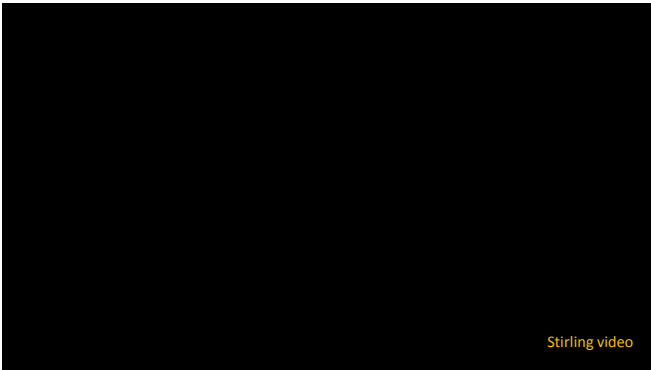
---

---

---

---

---




---

---

---

---

---

---

---

---

## Analysis of vibrations

### 1. Direct approaches

- Analysis of the vibrating body itself

---

---

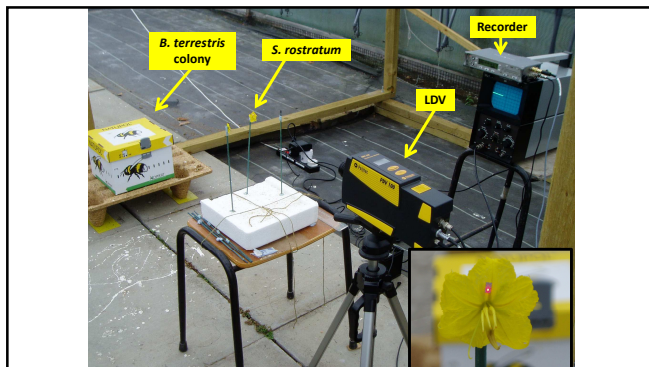
---

---

---

---

---



---

---

---

---

---

---

---

## Analysis of vibrations

### 2. Indirect approaches

- Analysis of the by-product of the vibrations, e.g., sound
- Requires relatively simple equipment
- Sensitive to background noise
- Sensitive to context of recording conditions

---

---

---

---

---

---

---

### Audio recorders

- Record vibrations transmitted through air (sound)



• H4n Zoom Recorder

---

---

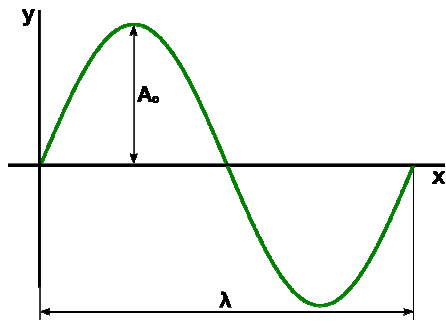
---

---

---

---

---



---

---

---

---

---

---

---

### Analysis using Audacity

---

---

---

---

---

---

---