

WING VENATION

Wing venation is considered a stable and one of the diagnostic character for identification of moths and butterflies for the last 210 years.

The procedure includes the separation of wings from the adult of a species by giving an upward jerk with the help of a fine needle. The detached wings were dipped in 70% alcohol to make them soft. Descaling was done with the help of sodium hypochlorite (approx. 4% w/v available chlorine solution). The descaled wings were then washed with distilled water and stained in 70% alcoholic eosin for 12-14 hours. After staining, the wings were passed to the upgrading series of alcohol before mounting in Canada balsam. The diagrams of fore and hindwing venation were drawn with the help of trisimplex projector which were later on scanned so as to make these available for showing venation.





Sujata, 2018

Moths vs Butterflies



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1. Moths tend to have flat wings while resting.
2. Moths are generally nocturnal, flying at night.
3. Hairy or feathery Antennae

1. Butterflies tend to fold their wings vertically up over their backs.
2. Butterflies are primarily diurnal, flying in the daytime.
3. Hooked shaped antennae



LEPIDOPTERA

- In the entire animal kingdom, insects form the largest group and Lepidoptera is the third largest order in the insect world (Zhang, 2013).
- This order has 1,57,424 known species under 15,578 genera comprising moths and butterflies (Zhang, 2011).

Hemiptera

Includes:

Assassin bugs, Lygus bug, Stink bug
Minute pirate bug, Big-eyed bug, Damsel bug

Mouthparts:

Piercing-Sucking

Charactersties:

The name Hemiptera means 'half wing'; because of the forewing structure, partially hardened at the base and partially membranous.



Orthoptera

Includes:

Indian House Crickets
Field Cricket
Short-horned Grasshoppers
Katydid (Long-horned Grasshoppers)

Mouthparts:

Chewing and Biting

Characteristics:

Cylindrical Body, with elongated hindlegs and musculature adapted for jumping. The antennae have multiple joints and filiform type



USER/SC-671

Hemiptera

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Assassin bugs, Lygus bug, Stink bug
Minute pirate bug, Big-eyed bug, Damsel
bug



Mouthparts:

Piercing-Sucking

Characterstics:

The name Hemiptera means 'half wing'; because of the forewing structure, partially hardened at the base and partially membranous.



Importance of Taxonomy

- To uniquely identify organisms begin with giving a name
- Understanding evolutionary biology (species, traits, relationships with other organisms)
- In conservation biology understanding patterns of biodiversity critical to policy making



Homoptera

Includes:

Leafhoppers

Treehoppers

Whiteflies

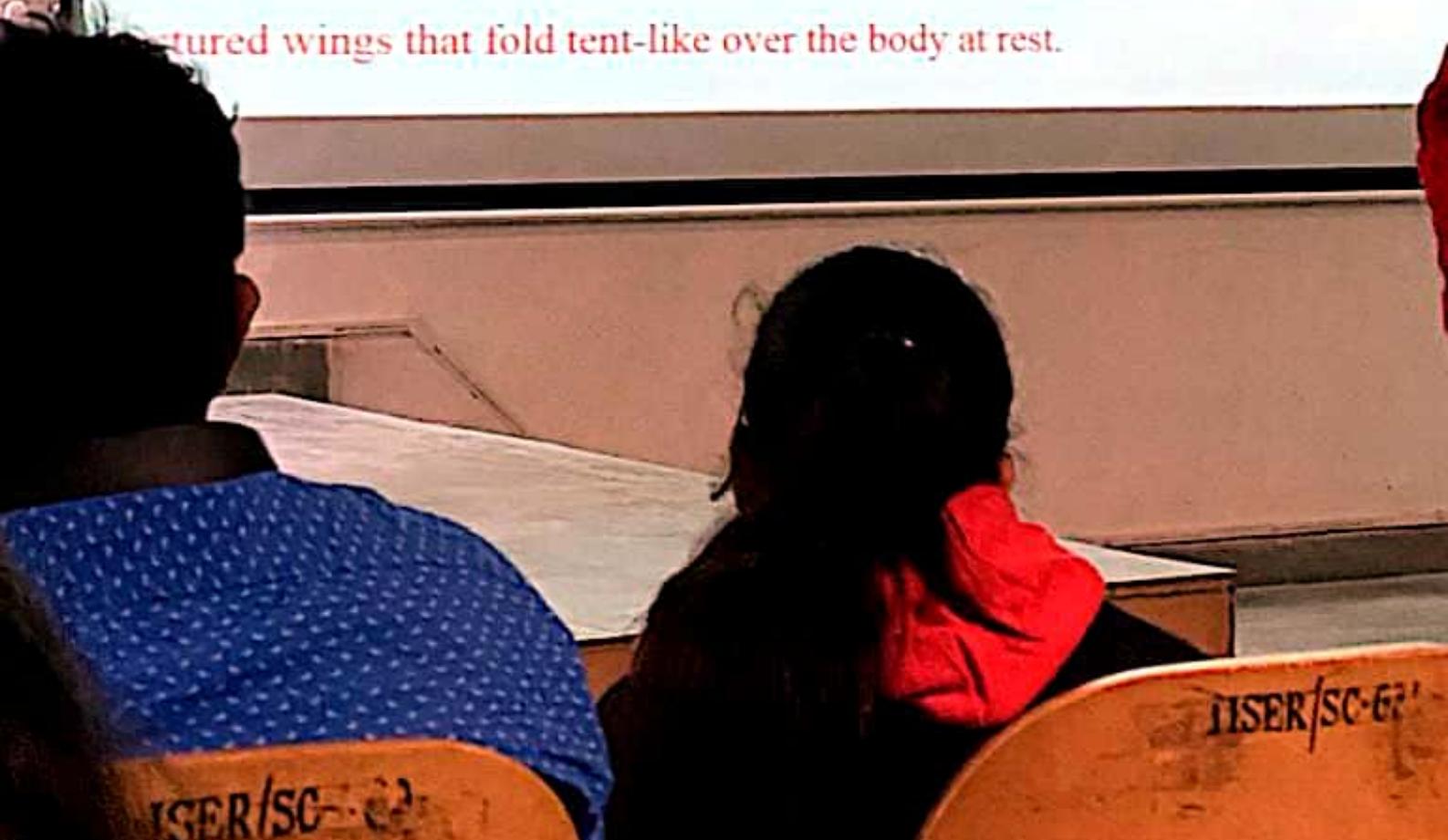


Mouthparts:

Sucking

Characteristics

The proboscis is shorter than that found in true bugs (Heteroptera). Although some Homoptera are secondarily wingless, the majority have membranous or uniformly textured wings that fold tent-like over the body at rest.



TISER/SC-62

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Taxa, community, assemblage, guild, e

- **Taxa:** Species of common descent. Forms a taxonomic unit. Co level of classification. Phylum, Class, Order, Family, Genus or sp
- **Community:** collection of species that occur together in space Ecological interactions occur between species as a consequence coexistence in time and space. They need not be species that s resources.
- **Assemblage:** collection of phylogenetically related members of community.
- **Guild:** Organisms that exploit the same set of resources in a sim manner.
- **Local guilds:** comprise of species that share resources AND belong to community
- **Ensembles:** Interacting species that share resources as well as

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- Local guilds:** comprise of species that share resources AND belong to the same community
- **Ensembles:** Interacting species that share resources as well as an environment.

Lepidoptera

Includes:

Butterflies and Moths

Mouthparts: Chewing – Caterpillars, Siphoning – adult.

Characteristics:

Derived from Greek word

Lepis: Scales

Pteron: Wings

The presence of scales that cover the body and wings.

The scales are modified, flattened "hairs", and give butterflies and moths their wide variety of colors and patterns



Coleoptera

Includes:

Blister beetle, Boll weevil, Darkling beetle, Dermestid beetle, Dung beetle, Lady beetle (Ladybird beetle), Striped June beetle

Mouthparts:

Chewing, Weevil- Piercing Sucking

Characteristics:

Coleoptera, derived from the Greek words "*koleos*" - sheath and "*ptera*" - wings, refers to the modified front wings which serve as protective covers for the hind wings. **Largest order.** At rest, both elytra meet along the middle of the back, forming a straight line, the most distinctive characteristics of the order.



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Importance of Taxonomy

- To uniquely identify organisms; begin with giving a name
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There are 31 different orders of insects

Some Important orders are:

Orthoptera

Hemiptera

Homoptera

Coleoptera

Lepidoptera

Diptera

Hymenoptera

Blattodea

Includes:

Indian House Crickets

Field Cricket

Short-horned Grasshoppers

Katydid (Long-horned Grasshoppers)

Mouthparts:

Chewing and Biting

Characteristics:

Cylindrical Body, with elongated hindlegs and musculature adapted for jumping. The antennae have multiple joints and filiform type

measuring abundance (evenness)

* evenness = ratio of observed diversity to maximum diversity

$$= \frac{H}{\ln(S)}, S = \text{all species recorded}$$

* Sorenson's coefficient of similarity

$$c_1 = \frac{a}{(a+b+c)} \text{ Jaccard diversity}$$

$$c_2 = \frac{2a}{(a+b+c)} \text{ Sorenson's coeff.}$$

a = no. of species common in site 1 & site 2.

b = no. of species recorded in site 1

c = no. of species recorded in site 2

* Co-exists of species.

what affect the abundance & distribution of species.

D) Species have phylogenetical limits to tolerate a range of physiochemical and environmental conditions.

2) Resource abundance & distribution

3) interaction with other species.

E) Endothermic organisms → these organisms can tolerate a wide range of temperature.
e.g. mammals.

$$\frac{\partial T}{\partial t} Q_p = (U + PV) - (U' + PV')$$

Endothermic → these organisms can tolerate only a narrow range of temperature
e.g. reptiles.

etc

ecological niche → It is the place or the role of a given species in its ecosystem.

It talks about limits, for all environmental features in a given ecosystem where a given species can potentially survive, grow and reproduce.

e.g. → grasslands for grazers.

niche differentiation → Two species differ in their niche requirement.

niche divergence → Is a evolutionary process by which niches of two species become less similar.

foot

Generalist organism.

These organisms are adapted to wide variety of range of environment conditions and exploits broad range of resources.

They have large niches. These organisms have wide range of motor skills.

$$U - U_1 = \Delta Q + (W_L + W_R)$$

$$W_V = \int P_2 dV$$

$$V_1 - P_2 V_1$$

$$+ P_1 V_1$$

$$J_T = \left(\frac{\partial T}{\partial P} \right)$$

$$+ \left(\frac{\partial H}{\partial P} \right)$$

$$- C_P \left(\frac{\partial T}{\partial P} \right)$$

$$= -C_P$$

$$\text{enthalpy}$$

$$= C_P$$

$$U =$$

$$T P$$

$$+ \frac{\partial U}{\partial T}$$

$$U =$$

$$T P$$

Biodiversity \rightarrow diversity in living organisms.

Biodiversity

two aspects of biodiversity

- richness \rightarrow different species present in a habitat.
- evenness \rightarrow abundance of those species.

alpha diversity \rightarrow diversity among species in a local habitat.

beta diversity \rightarrow diversity among species ^{among} b/w two different ~~specie~~ habitats but same geographical area.

gamma diversity \rightarrow diversity among species in two geographically different areas.

Taxa \rightarrow organisms with same descent

It can be at any level, species, family, order, kingdom etc.

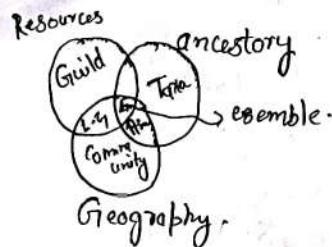
Community \rightarrow Species co-exist in space & time and have ecological interaction between them.

Guild Assemble \rightarrow Collection of species which exploit some resources in similar manner.

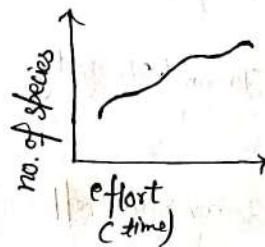
Guild Assemble \rightarrow Collection of phylogenetically related members of a community.

Local Guild \rightarrow Collection of species which exploit some set of resources in similar manner.

Esembles \rightarrow Collection of species of same community which exploit same set of resources in similar manner & are phylogenetically related. (have some ancestry).



* Species accumulation curves.



* measuring diversity.

measuring richness

$$H = -\sum p_i \ln p_i$$

$$p_i = \frac{n_i}{N} \rightarrow \text{proportional abundance of given species}$$

n_i = no. of individuals of given species.

N = Total no. of species.

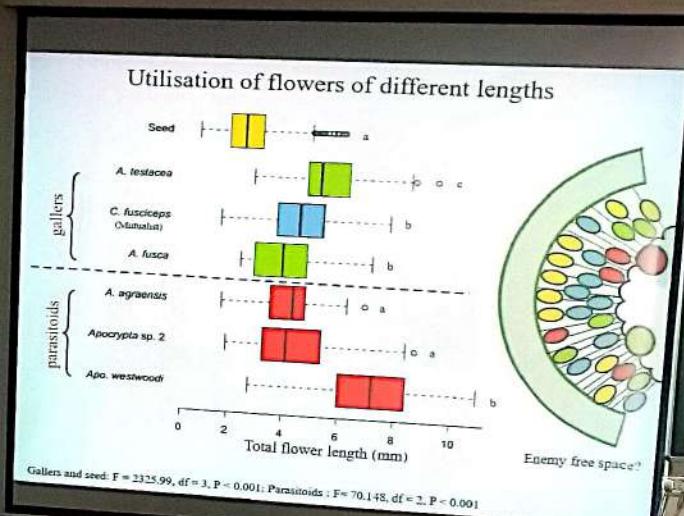
* Simpson's diversity index.

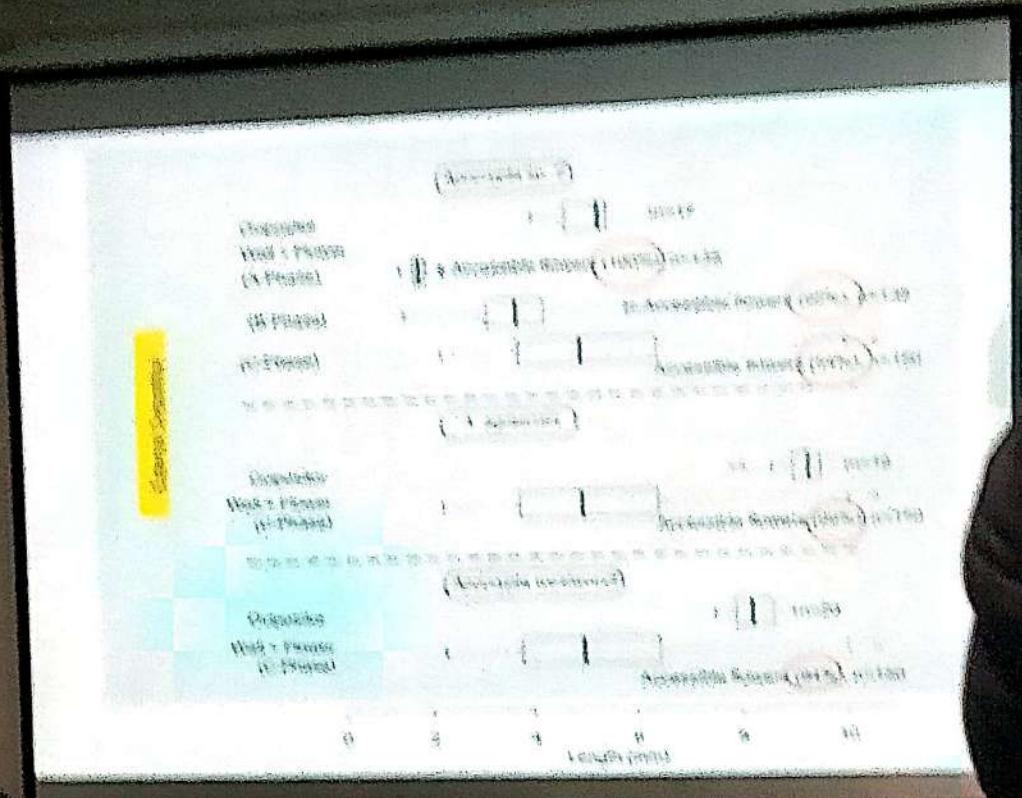
If two individuals are taken randomly from a given habitat what is the probability that they belong to same species.

$$D = \frac{\sum n_i(n_i-1)}{N(N-1)}, n_i \rightarrow \text{no. of individuals of given species.}$$

\Rightarrow Rel. probability be $1-D$

high the value of $1-D$ more diverse the ecosystem.



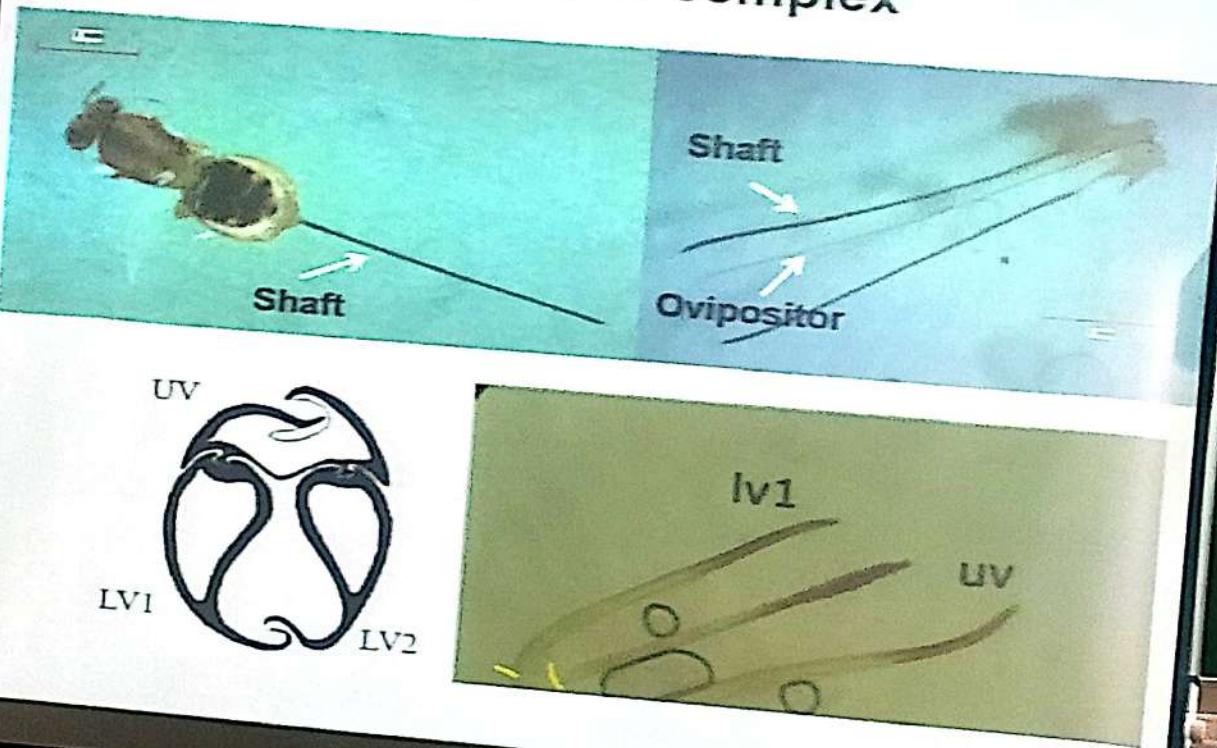


Ovipositor navigation

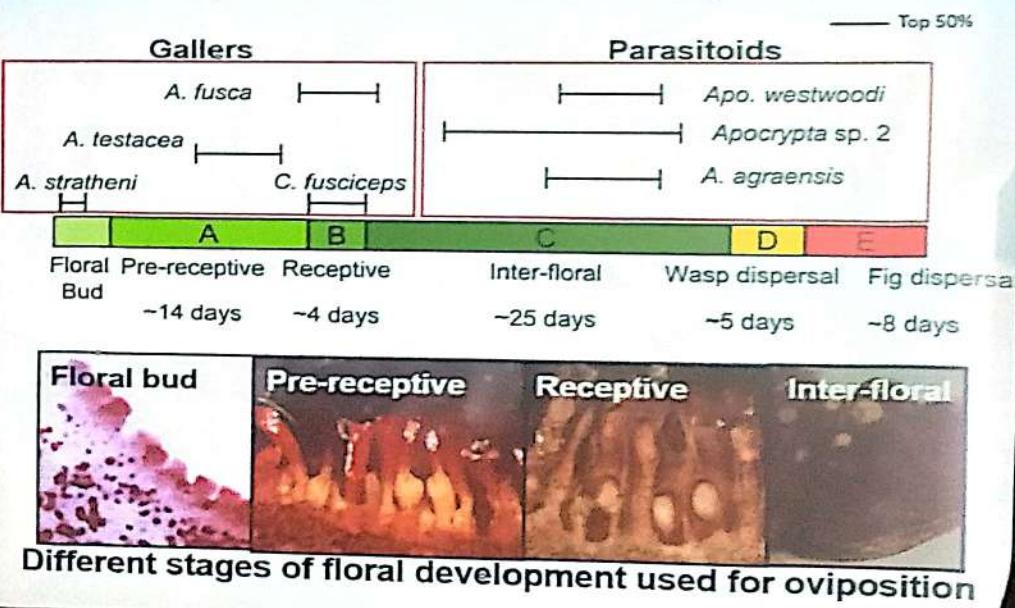


Flexible Ovipositor

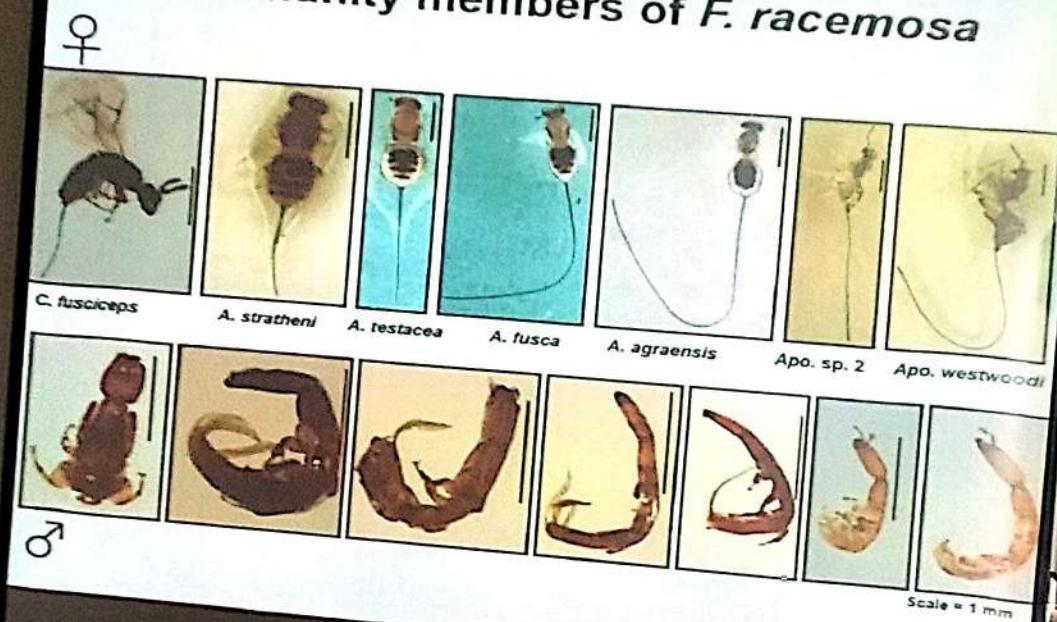
Ovipositor complex

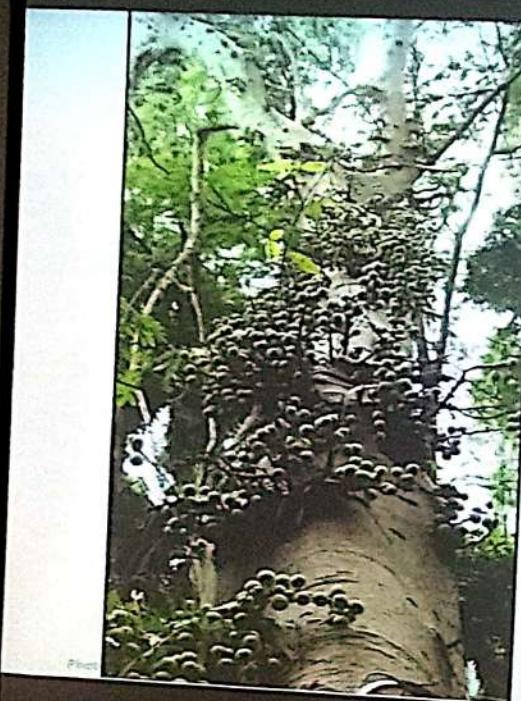


Temporal difference in oviposition



Community members of *F. racemosa*





Ficus racemosa

Family: Moraceae

Section: Sycomorus

Multiple cycles, Cauliflory,
30 m height

Wasp community—3 genera,
7 species (Chalcidoidea)

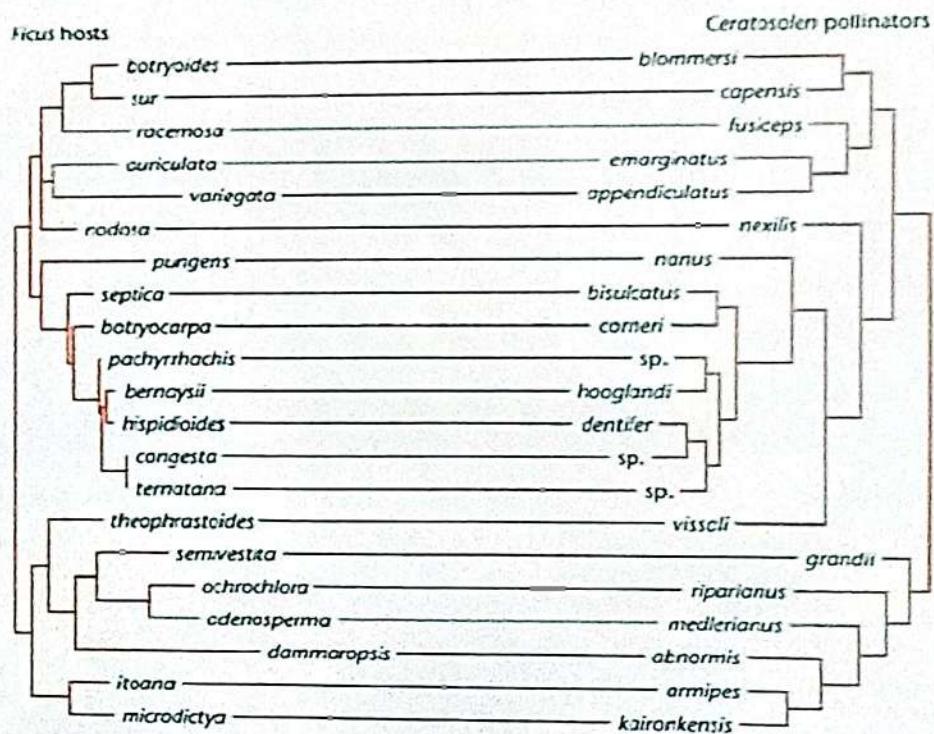
Pollinator

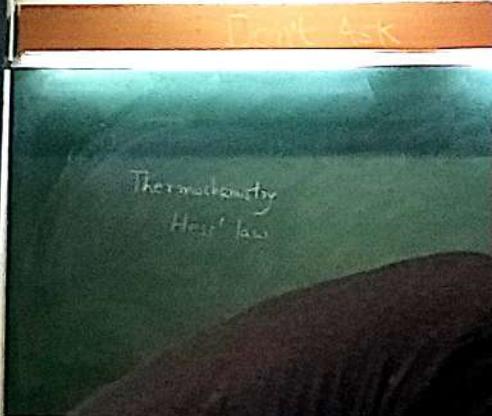
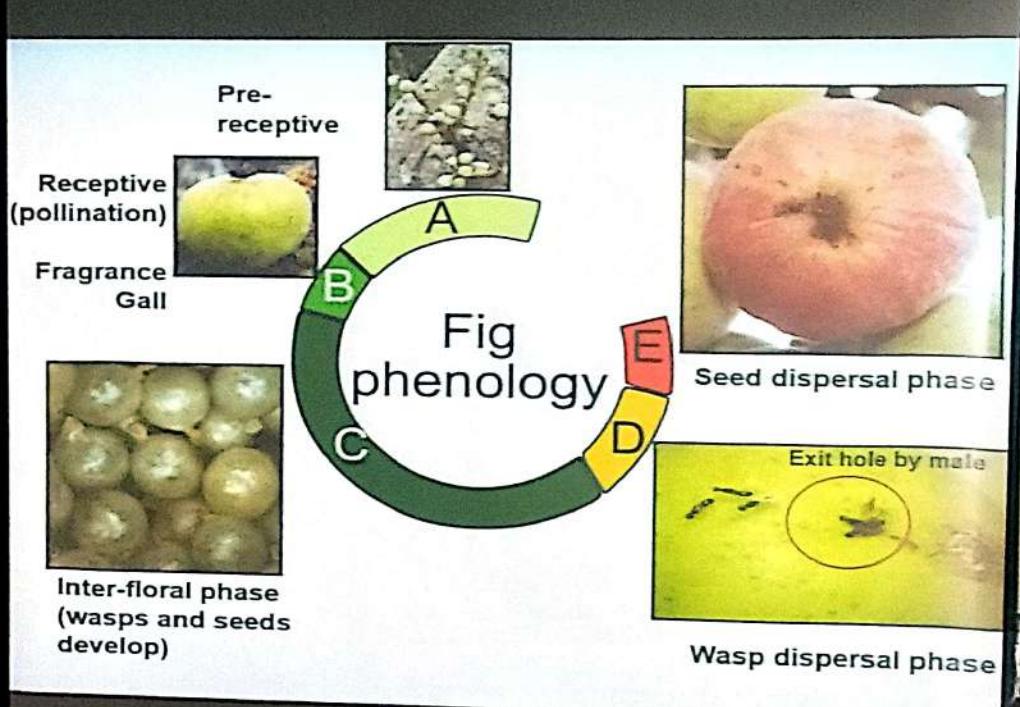
Ceratosolen fusciceps

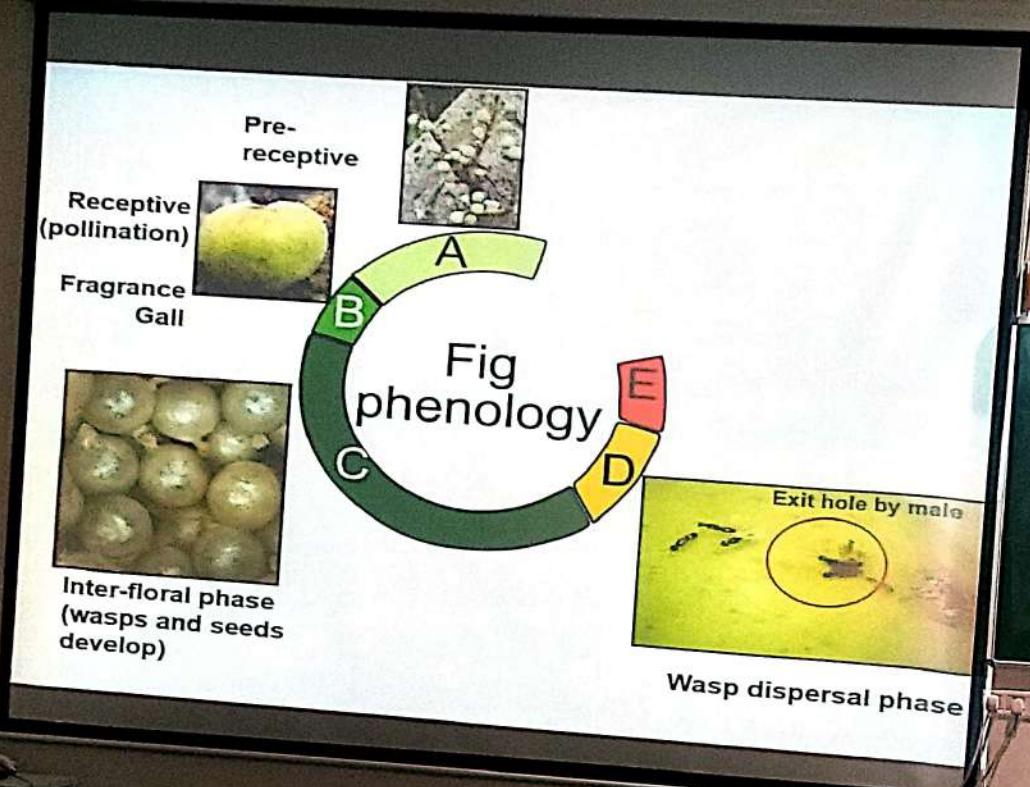
Exploiters

Apocryptophagus stratheni
Apocryptophagus testacea
Apocryptophagus fusca
Apocryptophagus agraensis
Apocryta sp. 2
Apocryta westwoodi

Co-diversification in Fig-fig wasp

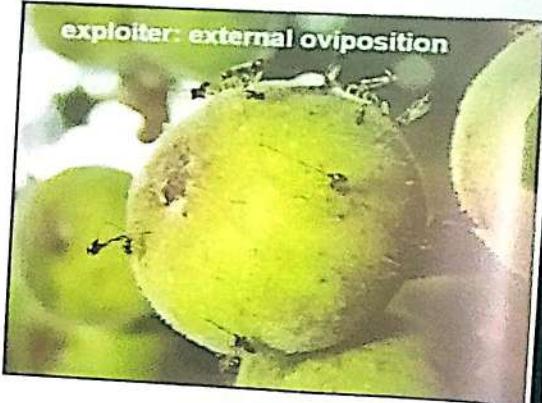
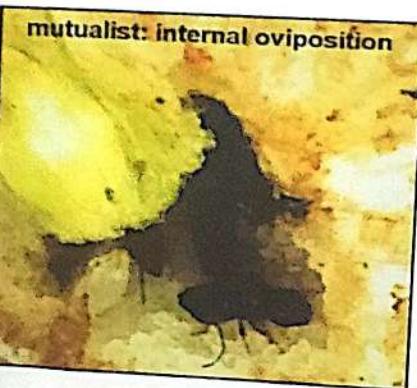






Draw Ask

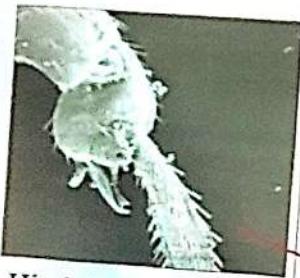
Thermodynamics
Hess' law



Thermodynamics
Hess' law

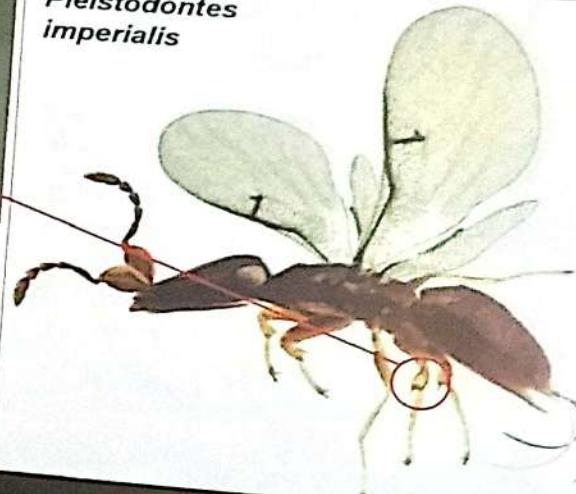


Morphology of Agaonidae: Morphological adaptations



Hind tibia bearing
strong spurs.

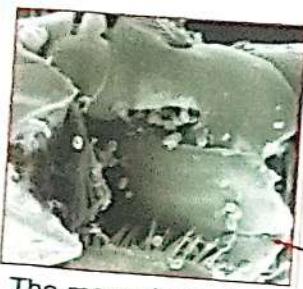
Pleistodontes
imperialis



Ostiole penetration



Morphology of Agaonidae: Morphological adaptations



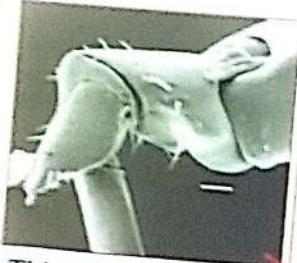
The mesopleura bear
pollen pockets. The
fore coxa pollen
combs.

Active pollination

Pleistodontes
imperialis

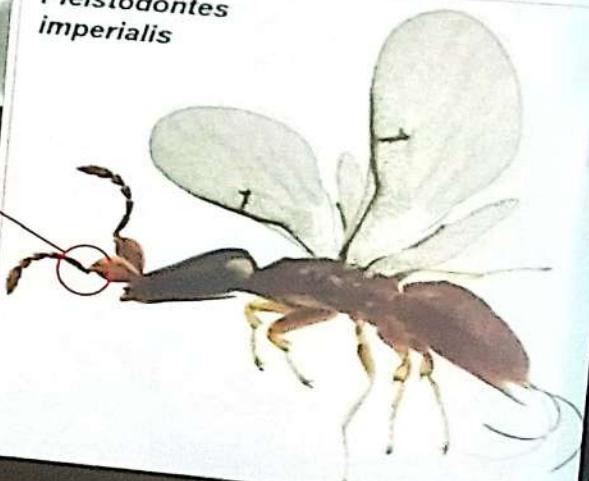


Morphology of Agaonidae: Morphological adaptations



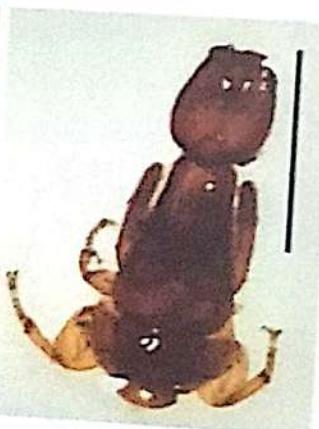
Third antennal
segment transformed
into a hook

*Pleistodontes
imperialis*



Penetration of the
ostiole

Pollinators of *Ficus*: The Agaonidae Chalcid wasps



Gallers

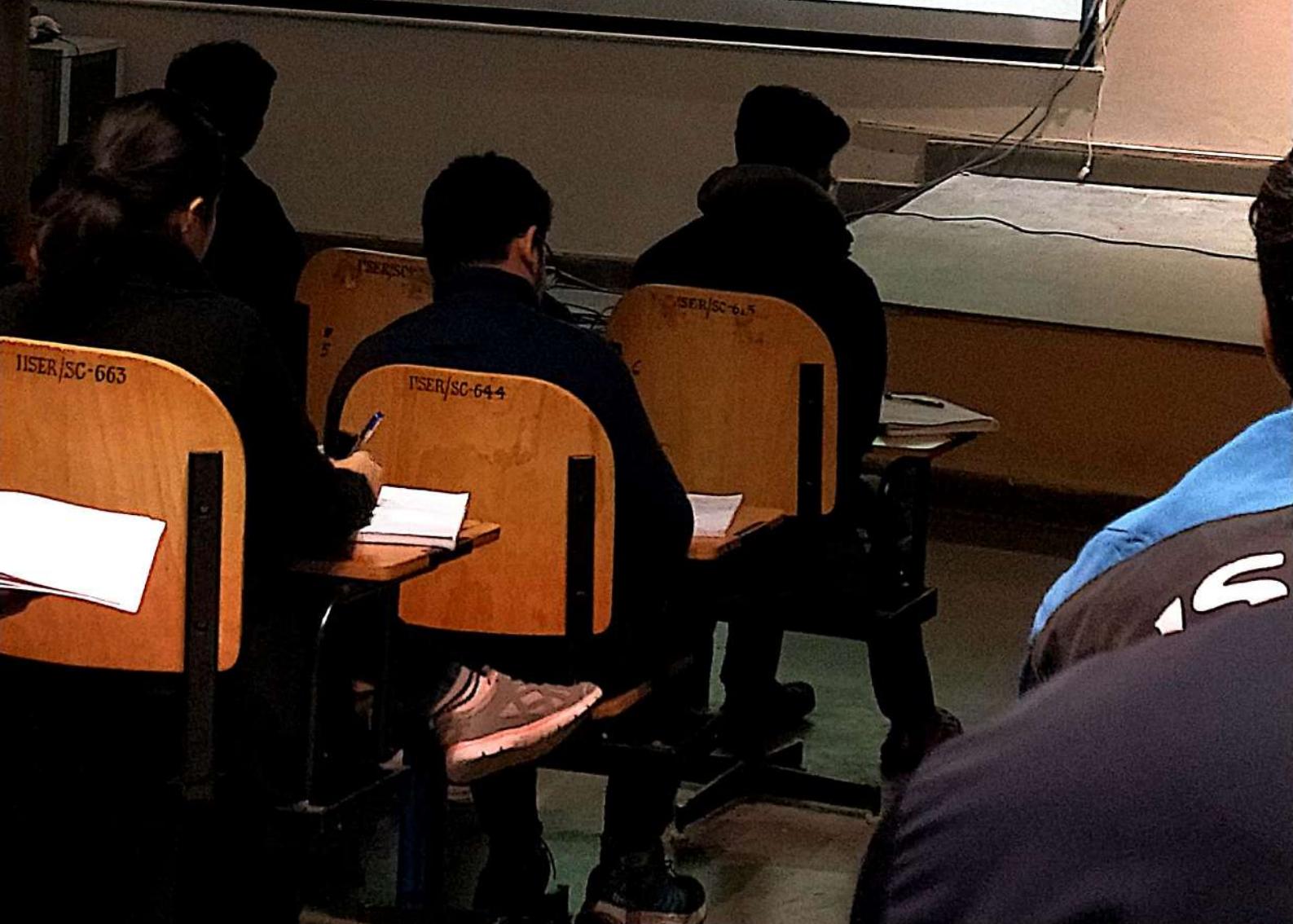
Enter fig through ostiole

Internal oviposition

Wingless males

Active or passive pollinators

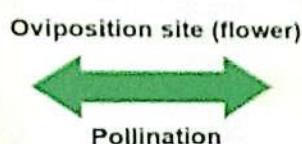
High inbreeding



Fig–fig wasp mutualism



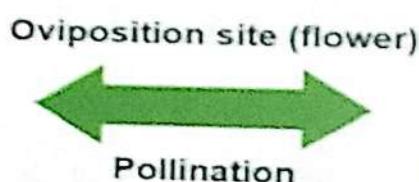
Fig (syconium)



Pollinator ovipositing
inside syconium

- Obligate interaction
- 80–90 million years old
- 750 unique associations
- Nursery pollination

Fig–fig wasp mutualism



Pollinator ovipositing
inside syconium

The genus *Ficus* (Moraceae)



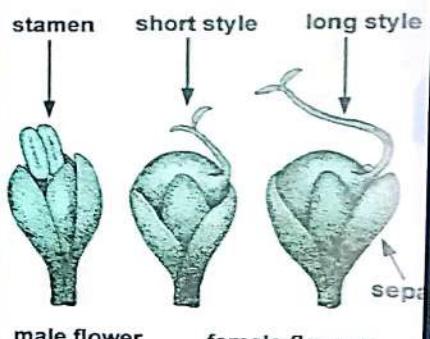
The fig: an urn shaped inflorescence (Hypanthodium)

IISER /

Fig syconium



view inside a syconium



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The genus *Ficus* (Moraceae)



Figs belong to genus *Ficus* (family Moraceae)



Wind and insect pollination



Jackfruit



Mulberry

Sexual deception



Ophrys sp.



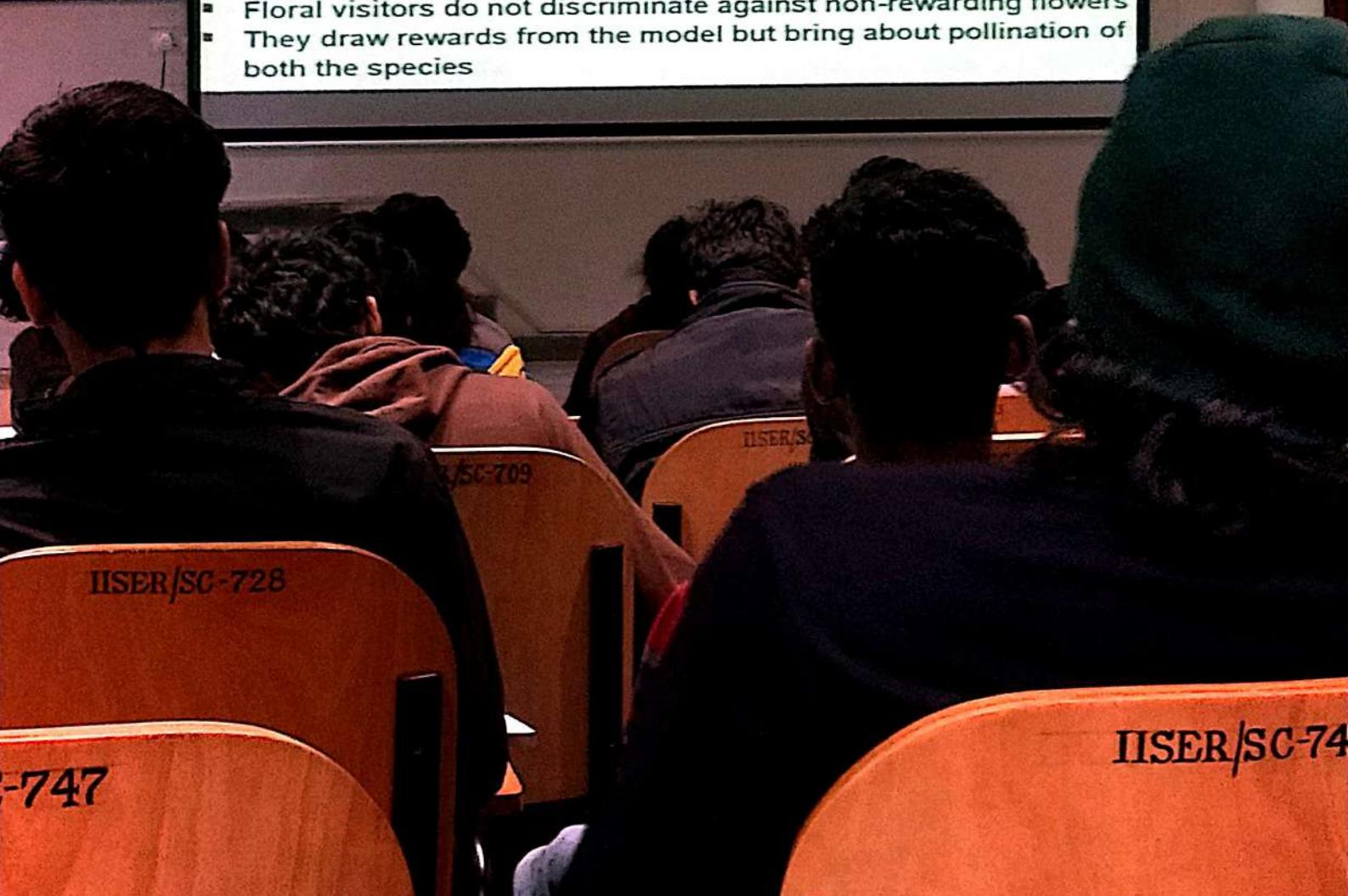
- Flowers do not offer any rewards but mimic virgin female of the pollinator
- Flowers emit fragrance similar to sex pheromones of virgin females of the visitor
- Male visitor gets attracted and lands on such flowers
- It tries to copulate (pseudocopulation), brings about pollination



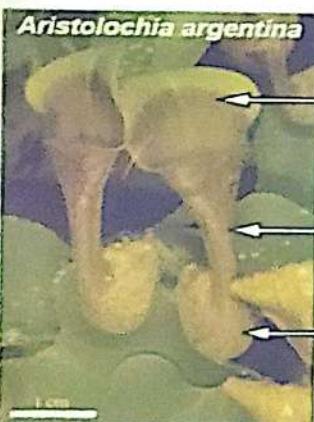
Food deception: common in orchid species



- Non-rewarding species (mimic) coexist with rewarding species (model)
- Flowers of the mimic resemble the flowers of the model
- Floral visitors do not discriminate against non-rewarding flowers
- They draw rewards from the model but bring about pollination of both the species



Brood-site deception: Trap mechanism



Flowers emit odour of decomposing plant materials, dung, carrion on which some insects oviposit.

(l – limb, g – gynostemium, t – tube, u – utricle)





Specialists

Darwin (1862) received a specimen of Madagascar orchid *Angraecum sesquipedale* that produces a long spur (25-30 cm) containing nectar at its tip. He predicted existence of exceptionally long-tongued moth for pollination of this orchid.

Wallace (1867), based on his studies on collections of hawkmoth from South Africa, reported African hawkmoth, *Xanthopan morgani* that has proboscis long enough to reach the bottom of the spur of *Angraecum* orchid and predicted the existence of such a moth in Madagascar.

Darwin's orchid



Generalists and specialists



Generalists pollinators: can visit many species of flowers
Generalist flowers: attract many species of pollinators

Rewards for pollination services

Pollen



Nectar



Resin



Heat

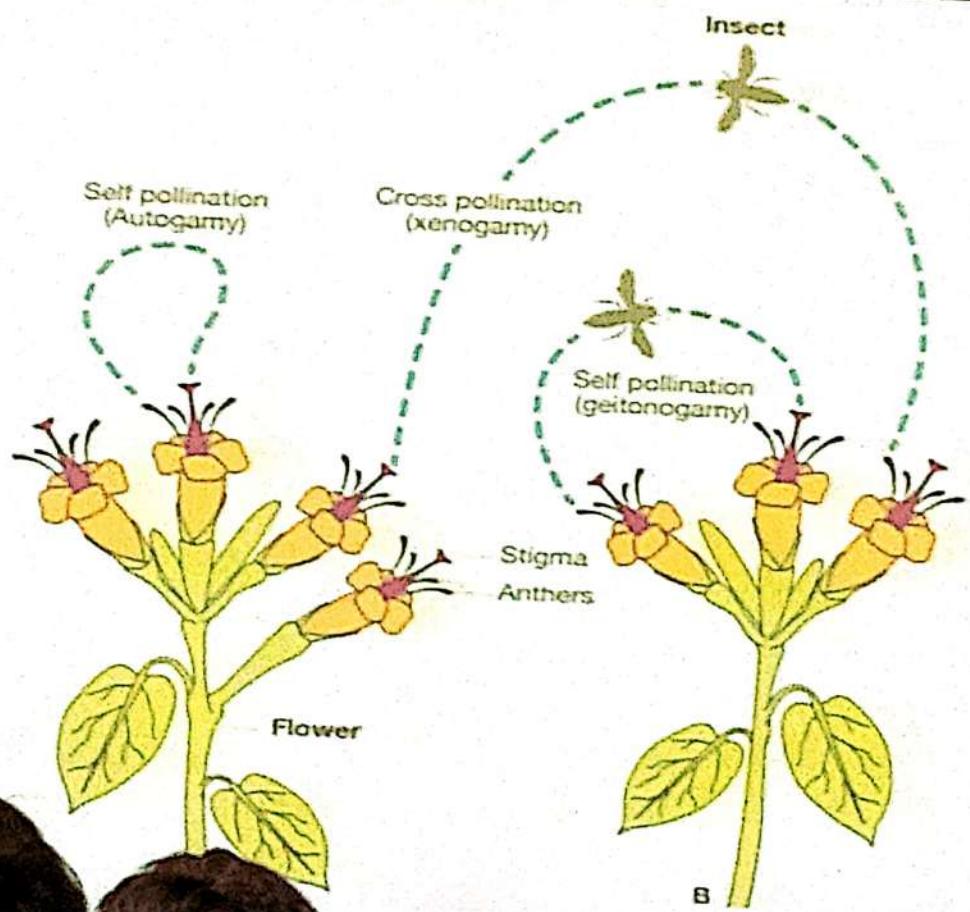


*Philodendron
sp.* - scarab
beetle
Cyclocephala



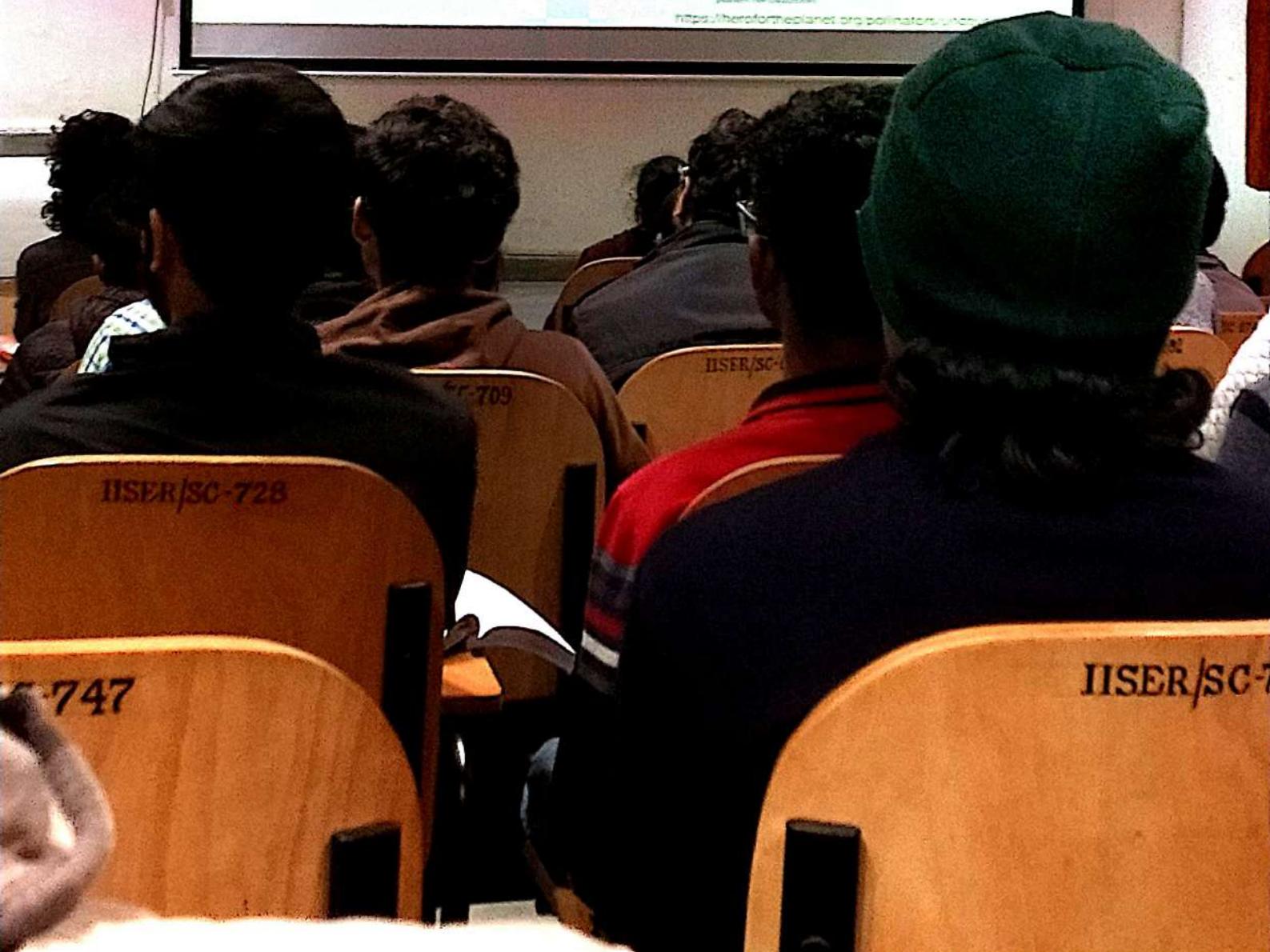
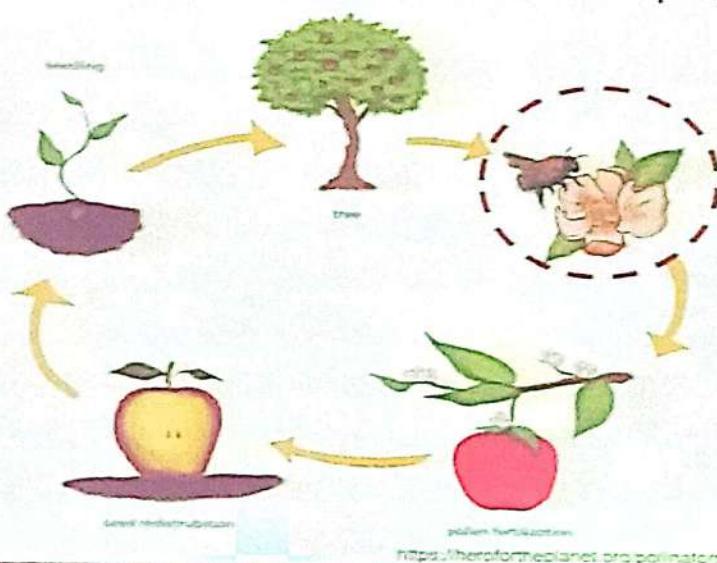
Photo source: google.com

Pollination syndromes are suites of floral traits that attract, reward, and facilitate pollination by a particular type of animal or abiotic agent agent (Faegri & van der Pijl, 1979)



Pollination

Transfer of pollen to the female reproductive organs of a plant, thereby enabling fertilization to take place.



CHIROPTERA

chiro = hand & ptera = winged (Greek)

MEGACHIROPTERA

- Fruit bats / Megabats
- Single Family, species diversity ca. 300
- Big eyes but small ears
- No echolocation capability but have high olfactory sensitivity
- Helps in pollination and seed dispersal

MICROCHIROPTERA

- Insectivore bats / Microbats
- Seventeen Families, species diversity ca. 1000
- Small eyes but big ears
- Have echolocation capability
- Helps in pest control

1300 sp. of bats have been reported across the globe (excluding polar regions!). A total of 123 species of bats are reported from South Asia, with the 111 species of microchiropterans bats and 12 species of megachiropteran bats.

MEGACHIROPTERA
(fruit bats)



MICROCHIROPTERA
(insectivorous bats)



Pic: Google Images

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Chiropterophily: pollination of plants by bats

- More than 528 species of Angiosperms worldwide are dependent on bats for pollination.
- Of these 528, 168 are pollinated by Megachiropteran Bats
- Remaining 360 species are pollinated by Microchiropterans
(Fleming et al. 2009)

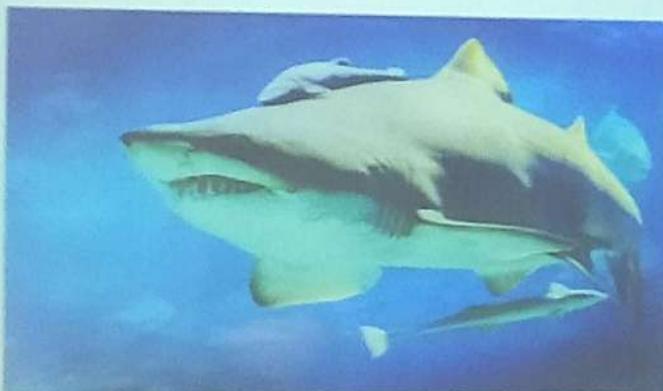


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Commensalism: sharing a table



Commensalism: A relationship where one organism benefits and other does not benefit but is not harmed either.

Shark and Remora fish interaction

Remora fishes are commensals

Free ride and left over food from their hosts

Shark unaffected by their presence

Ecological Interactions

- Competition
- Mutualism
- Parasitism
- Commensalism
- Predation

Morphological adaptation and co-evolution?

• A species of Philostomid bat (a microchiropteran species), *Anoura fistulata* has been studied by a group in Univ of Missouri St Louis

• The bat preys on several insects but also supplements its diet by consuming nectar from flowers

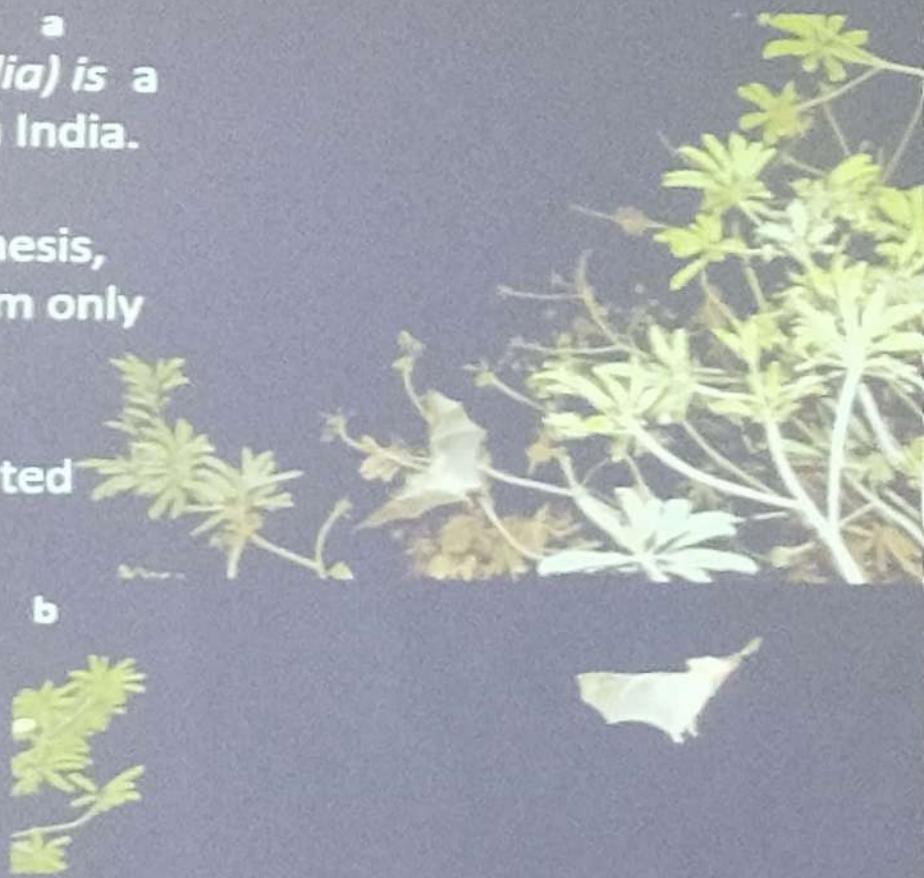
• It has an extraordinarily long tongue, which the author argues may have coevolved with the flower which it pollinates

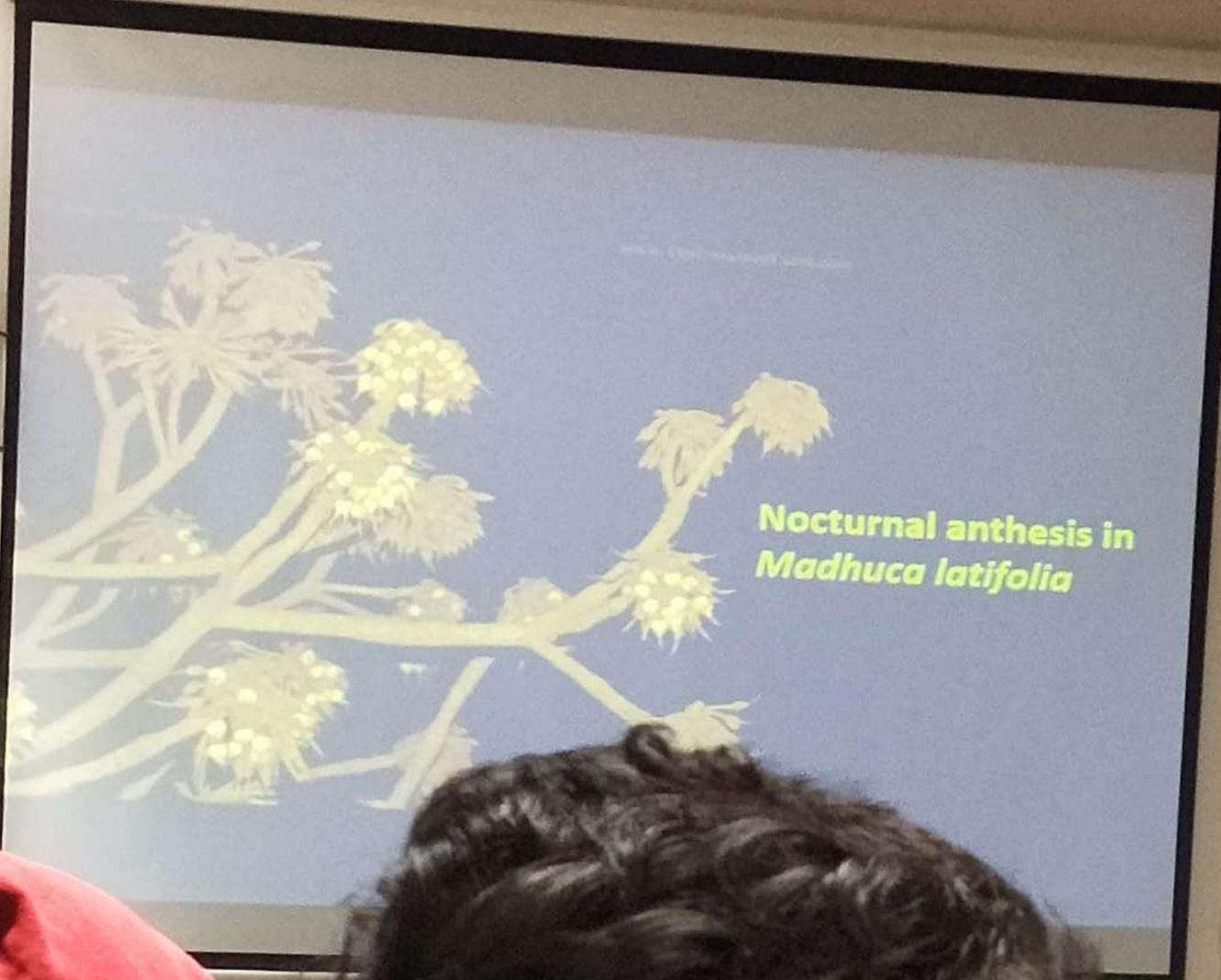
(Nectar bat: *Anoura fistulata* – (Nathan Muchhal, Nature 2006))



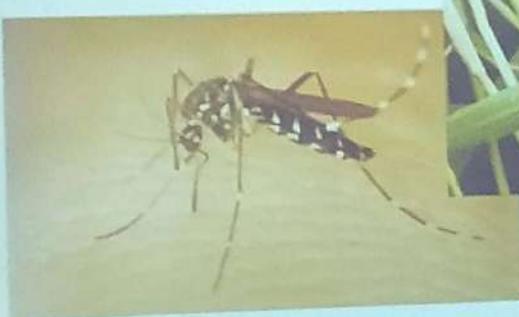
- Mahua (*Madhuca latifolia*) is a tropical tree also found in India.
- It exhibits nocturnal anthesis, meaning, Its flowers bloom only at night time
- These flowers are pollinated exclusively by bats

Madhuca latifolia

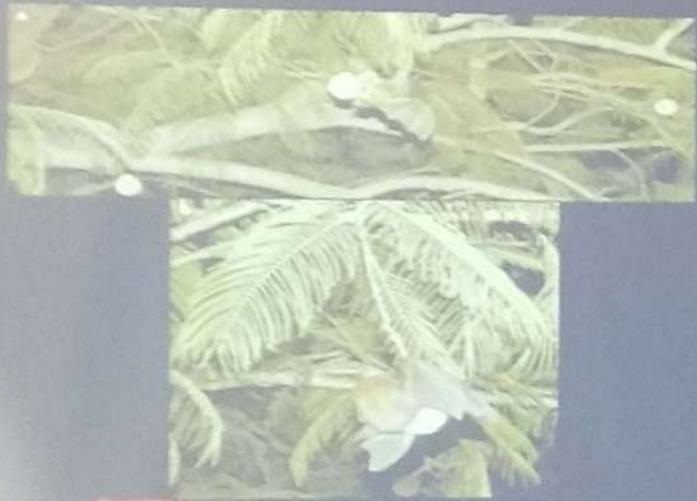




Parasitism



An ecological interaction in which one species benefits at the cost of the other. It is a negative interaction.



Pandian V. Chandran V.

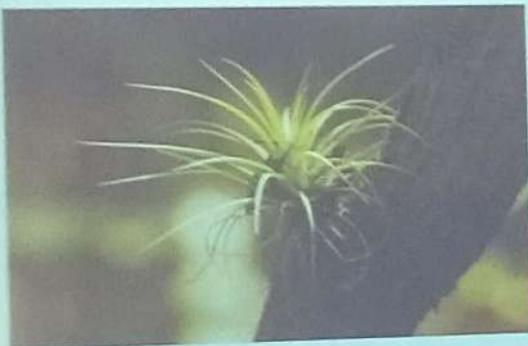
- Ball-badminton tree (*Parkia biglandulosa*) is a tropical tree also found in India.

- Only during night the flower secretes nectar

- These flowers attract any fruits bats and are majorly pollinated by bats alone

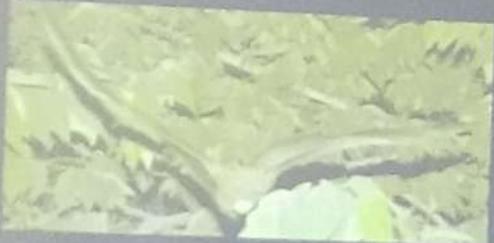


Orchids growing on branches of trees



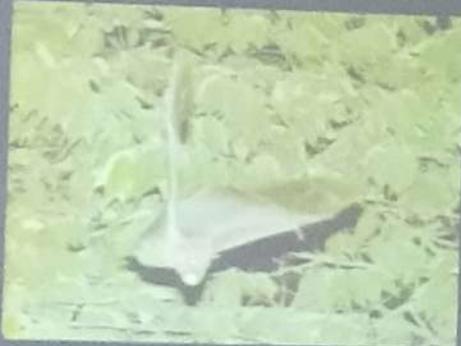
- Orchids are usually found in dense tropical forests.
- They form their base of attachment on the branches of trees, and benefit by getting adequate sunlight and nutrition that flows down the branches.
- The orchids do not grow to a large size, and thus the host tree is not harmed in any way.

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Are bats better dispersers than birds?

Cyanopterus sphinx consuming a *Muntingia calabura* fruit (Singapore Cherry) in Karaikudi, Tamil Nadu



**Cyanopterus sphinx* consume these fruits at different stages of ripening. Birds, however, selectively feed on ripened fruits only!

*The seeds are therefore dispersed by both bats and birds

*However, Birds exhibit (*In-situ* feeding) while bats fly with the fruits (*Ex-situ* feeding), hence better dispersers than birds!



Seeds of *Mallotus laevifolia*,
(Mahua) are also dispersed
exclusively by bats.



Chiroptechory: Seed dispersal by Bats

- As 50–90% of tropical trees and shrubs produce fleshy fruits adapted for consumption by vertebrates and the role played by frugivorous bats in dispersing these seeds is tremendous.
- Some species of fruit bats such as flying foxes cover long distances each night, defecating in flight, and scattering far more seeds across cleared areas than even birds
- Many bat-dispersed seeds are from hardy pioneer plants, the first to grow in the hot, dry conditions of clearings with up to 95% chance of germination
- Frugivorous bats play important role in the early stages of forest succession

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Crypsis: avoiding detection

One of the many ways of crypsis is camouflage

-759

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Predator Avoidance

Predator Activity	Prey Adaptation
Search for Prey	a) Crypsis
Prey Recognition	Mimicry* Polymorphism*
Pursuit / Catching Prey	a) Escape flights, b) 'startle' response c) Weapons of defence d) Aposematism
Handling Prey	Active defence, spines, shell, toxin

Polymorphism: predator search image



Karpestam et al 2016

- 1) Visual predators that exploit polymorphic prey suffer from reduced performance.
- 2) This happens due to the reduction of predator's ability for associative learning due to an overabundance of form.
- 3) Support for hypothesis that prey colour polymorphism may afford protection against predators for both individuals and populations.
- 4) This protective effect provides a probable explanation for the longstanding, evolutionary puzzle of the existence of colour polymorphisms.

- Visual predator; Search Image; Pattern matching
- Countering a search image in predators
- Countering associative learning

SC-759

ISER

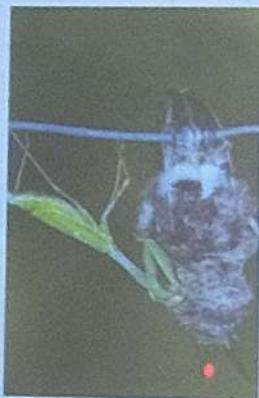
- Müllerian mimicry:
two aposematic
noxious forms
conform to the same
coloration/patterns of
warning signal in
order to avoid a
common predator
- Shared cost and
benefit

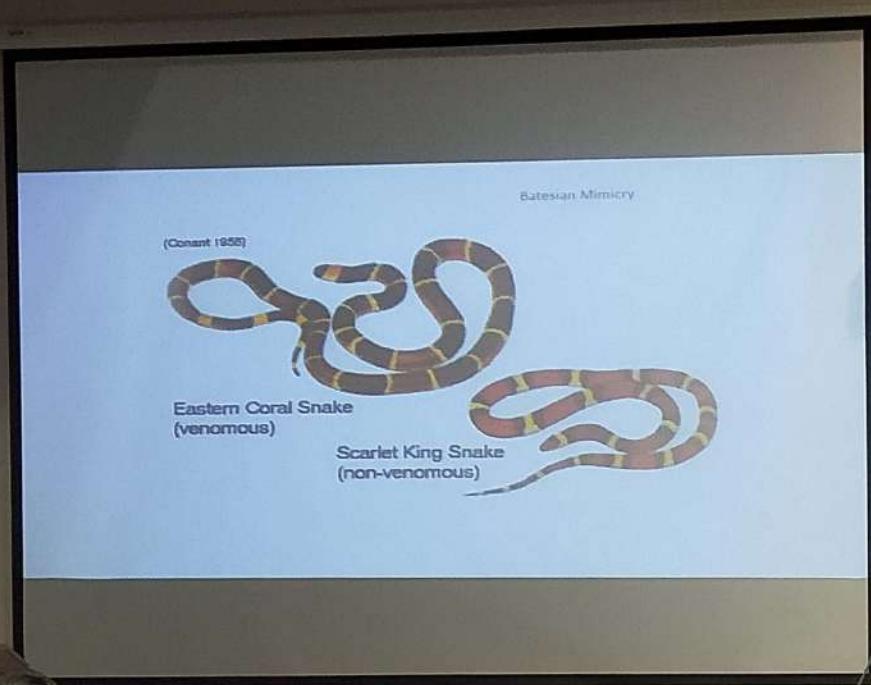


PICT: wiki
Different species of
Heliconius butterflies

Predation

Megan Ralph





- **Batesian mimicry:** Named after the english naturalist Henry Walter Bates, for his work on butterflies in the rainforests of Brazil (1852)
- A palatable, harmless species resembles an unpalatable/toxic species that is noxious to predators
- Relies on associative learning of predators (learning to avoid individuals that look like the noxious unpalatable species)

Mimicry

Honest and dishonest signals

- Mimicry: A form of crypsis (usually visual) where an animal looks or behaves like another organism or object in order to avoid detection
- Can be used by prey or predator

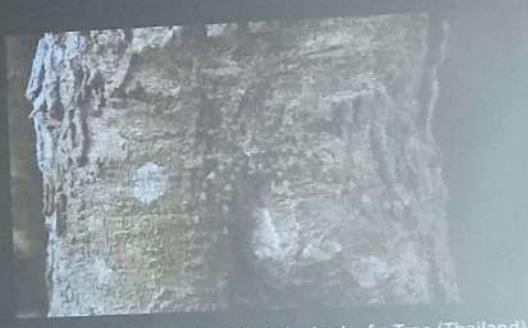
Batesian mimicry
Mullerian mimicry

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Satanic Leaf-tailed Gecko (Madagascar)

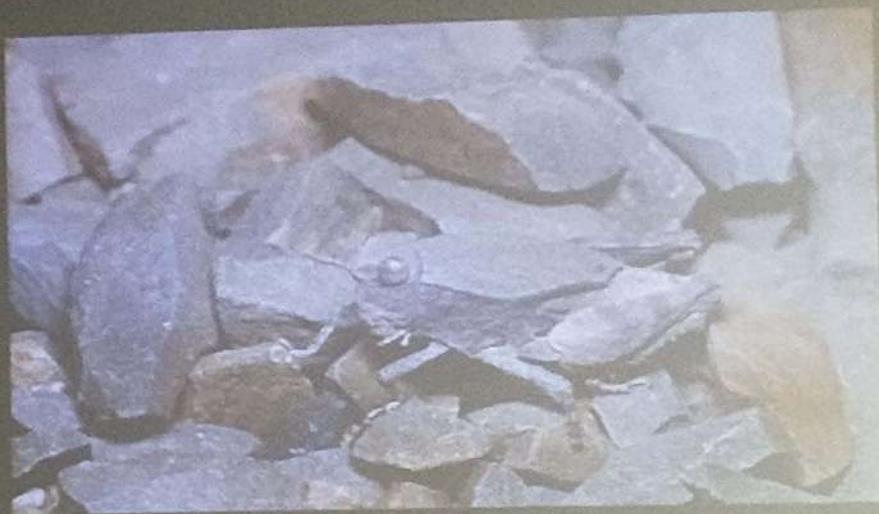
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A lichen spider camouflaged on the bark of a Tree (Thailand)

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A Male Shale Grasshopper mimics the stones it sits on

In the Neotropics bats have been shown to approach katydid calls

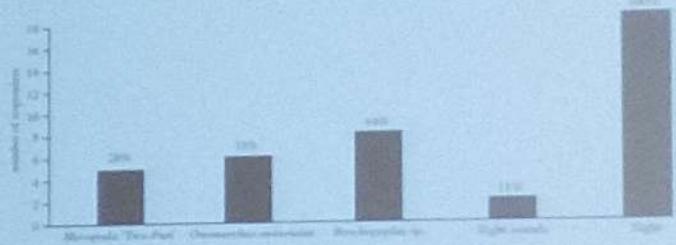
Diet analyses confirm bat predation on katydids

Neotropical katydids reduce signalling in presence of bats

What about the Paleotropics?

- Assessing relative predation risk posed to male and female katydids by *Megaderma spasma* using diet analysis (prediction: males should be preyed upon more heavily than females)
- Playback experiments to examine eavesdropping on calling males





- 1) Analysis of culled remains under *M. spasma* roosts indicated that female katydids were consumed in much higher numbers than males
- 2) Bats are eavesdropping on calls as well as sound of flight
- 3) Calling males face 1/3rd of bat attacks faced by females

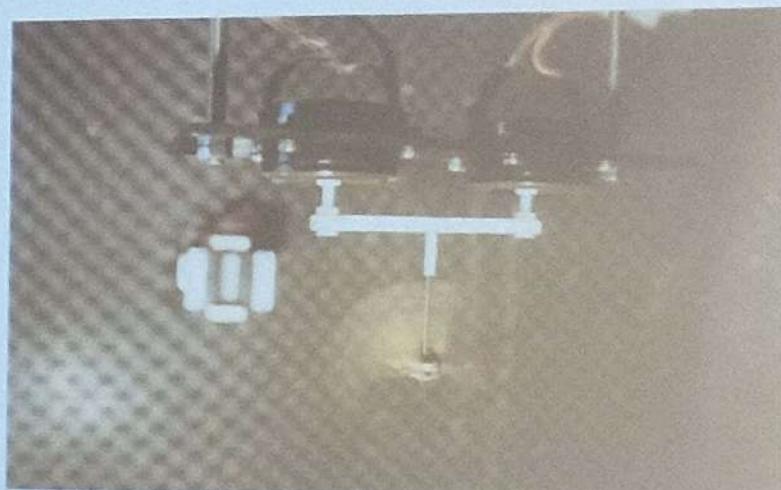
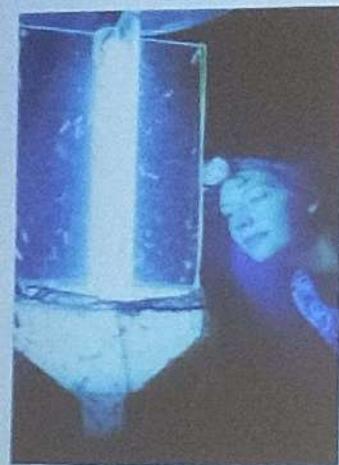
Raghuram et al Proc. R. Soc. B 2015

Moth-bat interactions

- Microbats use echolocation to navigate AND find food
- These nocturnal predators can use echolocation to not only detect movement (live prey) but also its shape, size and texture
- Many moths are eared (they have ears)
- They can employ these to hear their hunters and devise counter strategies
- Escape flight in moths is one of the many antipredatory strategies of moths against their predator
- Escape flight are erratic, with zig-zag patterns, loops, sharp turns



Escape flight polymorphism?



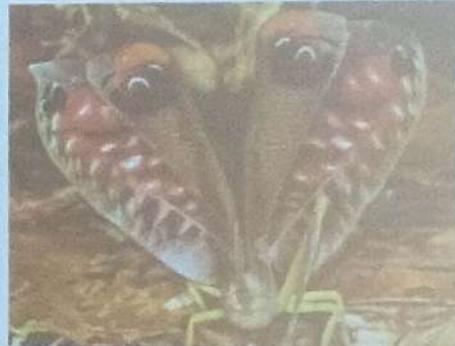
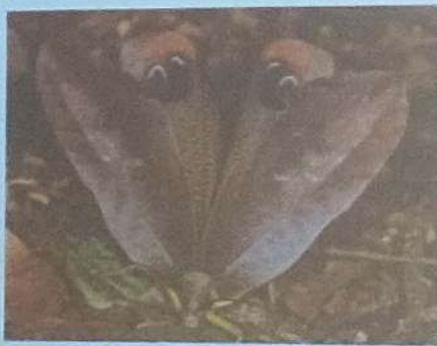
© Theresa Hügel; source:
<https://www.mpg.de/13647825/each-moth-escapes-its-own-way>

Flying moth tethered to the membranes of speaker
Moth's erratic flight were picked-up by speaker membrane
And transduced to electric signals. Each one is different

Startle predator.

Underwing moths flash bright hindwings when pecked.

Many animals scream. Loud cries may induce predator to let go
(distress calls to attract group members?)



Aposematism

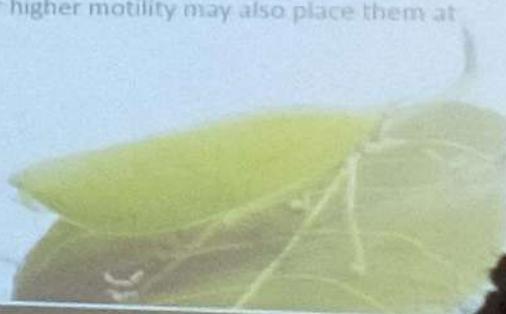
- Aposematism: Apo (away) sema (sign): Warning colouration is the phenomena by virtue of which prey species use a warning signal to indicate their noxious or toxic form (or unpalatability) to potential predators.

This kind of signalling is beneficial to both prey and predator.

Bats as predators of katydids



- Who is at higher risk? Singing males or silent females?
- Katydid Males produce loud and conspicuous calls for mate attraction putting them at high risk of predation from eavesdropping predators.
- Silent females approach signalling males; their higher motility may also place them at risk.



Adaptations and counter-adaptations

Predator Activity	Predator Adaptation	Prey Adaptation
Search for Prey	a) Improved sensory acuity to find prey* b) Search in prey-abundant area	a) Crypsis b) Spacing
Prey Recognition	Learning Pattern Recognition	Mimicry* Polymorphism*
Catching Prey	Motor Skills Speed, Agility; Hunting Tactics * Weapons of offence	Escape flights, 'startle' response Weapons of defence Aposematism
Handling Prey	Subduing Skills Detoxification	Active defence, spines, shell, toxin

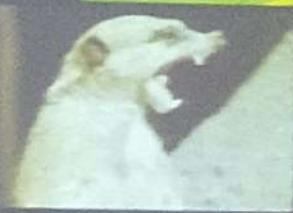
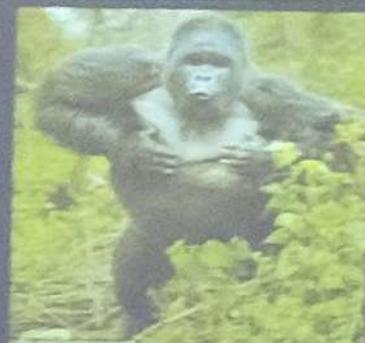
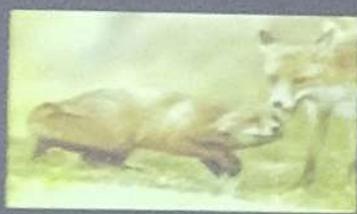
Adapted from Krebs and Davies, 1983.

Evolutionary Arms Race

- Initially, even slight and very crude adaptations could confer a selective advantage
- Improvements in one of the two parties (predator/prey) then selected for improvement in the other
- This results in improved counter-adaptations
- Can they serve as a starting point for an evolutionary arms race?
- How does the race end? Does it ever? Can predators become such efficient hunters such as to drive prey to extinction? And vice-versa
- Red-Queen Hypothesis (keep running to stay at the same place); coevolution of competing species



Functions



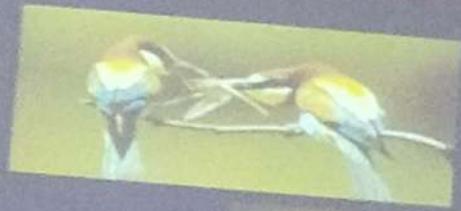
Mate Attraction

Strategies for mating

- Follow female
- OR
- 'perform' in order to attract



Nuptial gifts



The AXE Effect ;)



P. ornata perfumed gifts



T. oceanicus CHC



**Singing and dancing for love:
Animal communication
for mate attraction**



Manjari Jain
Special Lecture
14th Feb 2020

IISER/SC-691

Singing and dancing for love



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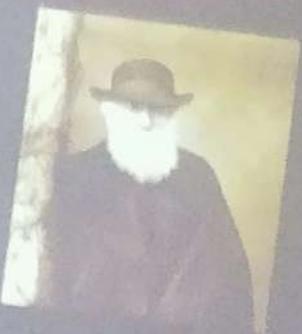
Signal diversity and function

- **Enormous diversity of signals in nature**
- **Diverse structure and diverse functions**
- **Diverse tasks in the daily lives of animals**
- **Animal communication modulates many behaviours**

Darwin's theory of Sexual Selection

- Theory of Natural Selection: Inadequate to explain the evolution of 'wasteful', extravagant, cumbersome secondary sexual characters.

- Darwin argued that such characters could not have been shaped by natural selection as they were likely reduce the fitness of the bearer



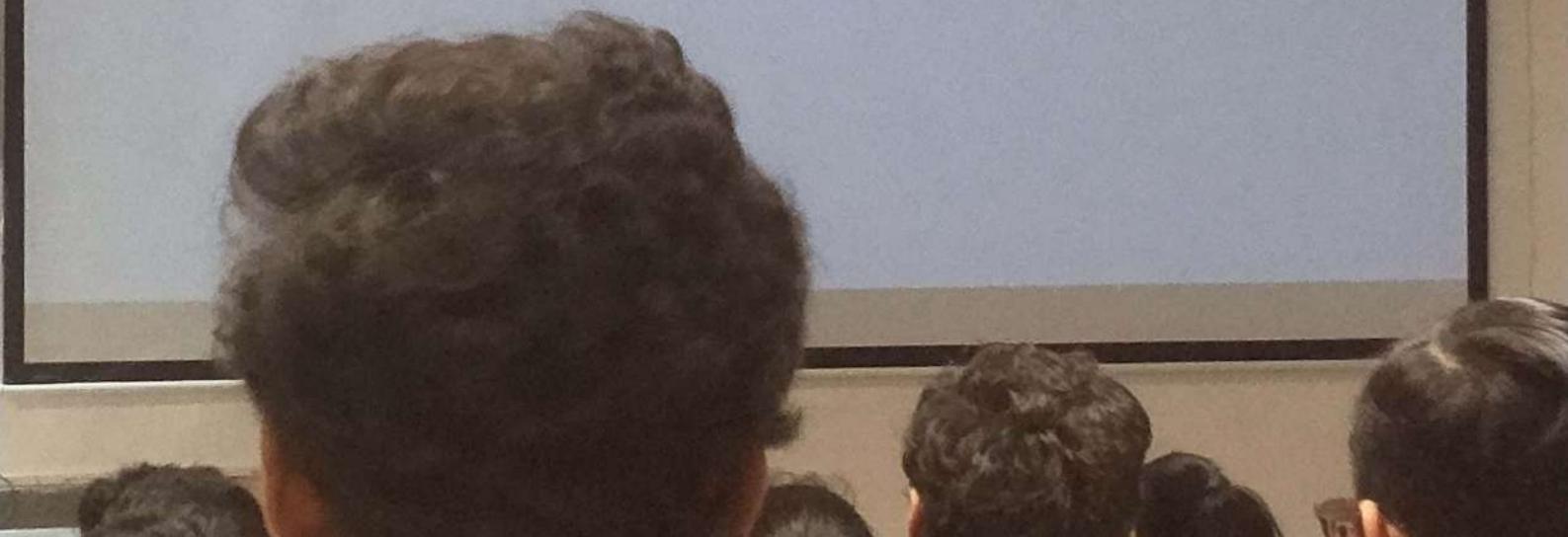
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Animal Communication

"The action of, or cue given by one organism (the sender) is perceived by and thus alters the probability pattern of behavior in another organism (the receiver) in a fashion adaptive to either one or both of the participants"

(Wilson 1975)



Sexual Selection

- Sexual Selection: 'the advantage which certain individuals have over other individuals of the same sex and species, in exclusive relation to reproduction'
- Sexual selection by male-male competition OR female choice
- Peacock's train could not be explained by male-male competition; Darwin pitched for female choice
- Darwin failed to find a suitable explanation as to WHY females should choose males with such extravagant traits

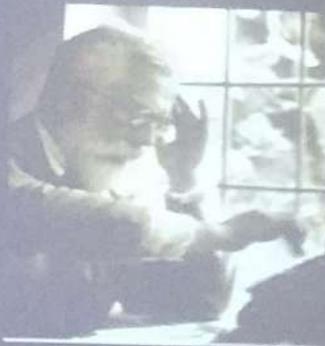
Gestural/Tactile



Fisher's Runaway selection

- 100 years later Fisher proposed:
- Slight exaggerated characters indicators of male quality
- Females preference for slightly exaggerated character
- Males with exaggerated character get to reproduce; sons have exaggerated characters, daughters have a preference for it

This feedback loop continues resulting in superlative exaggeration even at the cost of the survival of males.



Acoustic



Beauty vs Honesty

- According to Fischer's theory, extravagant characters evolve INSPITE of reduction in fitness.
- Although the slight exaggeration may have been correlated to male quality, extreme exaggeration is selected merely for beauty?
- This implies that superlative traits compromise on fitness thus they are no longer true indicators of male quality.

This makes a peacock, merely beautiful and NOT honest



C-728

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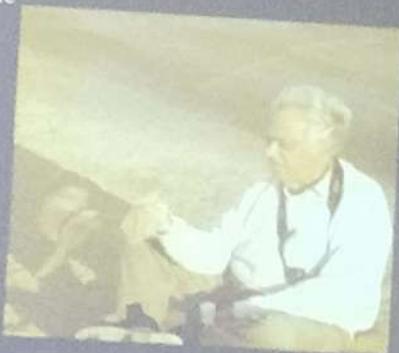


Visual



The Handicap Principle

- Signals are honest or reliable when they signal the true quality of signaler
- Honest signals must be costly
- Only high quality signalers can 'afford' to produce costly signals
- Peacocks with elaborate trains have been found to be better survivors with larger fat reserves and higher levels of immunocompetence.
- Elaborate train is an honest indicator of male quality



Olfactory



Conclusion



- Peacocks with elaborate trains are selected because of the handicap they carry rather than in spite of it
- A peacock, thus is not merely beautiful, it is also honest!
- Adaptive/Utilitarian (?)

Gadagkar, R. (2003). Is the peacock merely beautiful or also honest?
Current Science, 85 (7) 1012-1020

Population ecology is concerned with measuring changes in population size and composition and identifying the factors that cause these changes.

Population = individuals of one species simultaneously occupying the same general area, utilizing the same resources, and influenced by similar environmental factors.

No population can continue to grow indefinitely.

- Many populations remain relatively stable over time with only minor increases and decreases.
- Other populations show dramatic increases followed by equally dramatic decreases.

Population Ecology

Population ecology is the study of populations in relation to the environment. It includes environmental influences on population density and distribution, age structure, and variations in population size.

B. Patterns of Dispersion

A population's geographical range is the geographic limits within which a population lives.

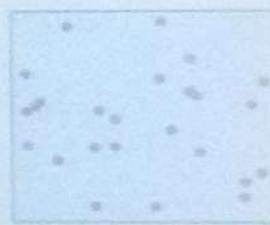
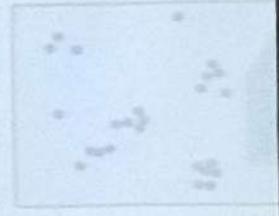
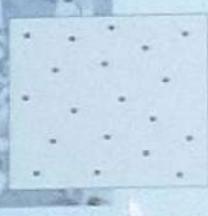
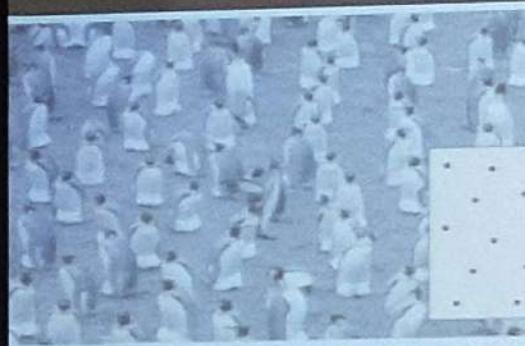
- Local densities may vary substantially because not all areas of a range provide equally suitable habitat.

Individuals exhibit a continuum of three general patterns of spacing in relation to other individuals: *clumped*, *uniform*, and *random*.

A. Measuring Density

It is usually impractical or impossible to count all individuals in a population, so ecologists use a variety of sampling techniques to estimate densities and total population size.

- May count all individuals in a sample of representative plots. Estimates become more accurate as sample plots increase in size or number.
- May estimate by indirect indicators such as number of nests or burrows, or by droppings or tracks.
- May use the *mark-recapture method*.



L Two important characteristics of any population are density and the spacing of individuals

Every population has geographical boundaries and a population size.

- A population will exhibit two characteristics within its boundaries: *density* and *dispersion*.

Population density = The number of individuals per unit area or volume.

Population dispersion = The pattern of spacing among individuals within the geographical boundaries of the population.

1. A *clumped* pattern is when individuals are aggregated in patches.
 - May result from the environment being heterogeneous, with resources concentrated in patches.
 - May be associated with mating or other social behavior in animals.
 - May also be associated with defense against predators.
2. A *uniform* pattern is when the spacing of individuals is even.
 - May result from antagonistic interactions between individuals of the population.
 - For example, competition for some resource or social interactions that set up individual territories for feeding, breeding or nesting.
3. A *random* pattern is when individual spacing varies in an unpredictable way.
 - Occurs in the absence of strong attractions or repulsions among individuals.
 - Not very common in nature.

The marking technique must not harm the individual or affect its survival by predation.
The mark must not wash off or wear away.
There must be no immigration into or emigration out of the population.
There must be no mortality between the mark and recapture times.
The marking experience must not make an individual more or less likely to be recaptured.

In the *mark-recapture method*, animals are trapped within boundaries, marked in some way and after time retrapped.

- The number of individuals in a population (N) is estimated by the formula:

$$N = \frac{\text{(number marked)} \times \text{(total catch the second time)}}{\text{number of marked recaptures}}$$

- Assumes marked individuals have same probability of being trapped as unmarked individuals. This assumption is not always valid.



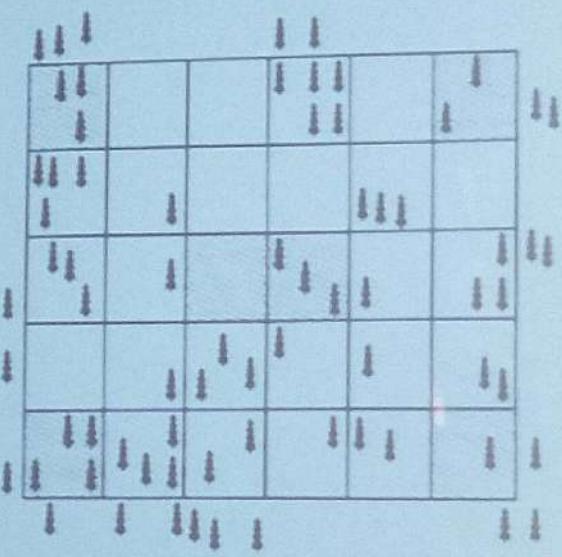
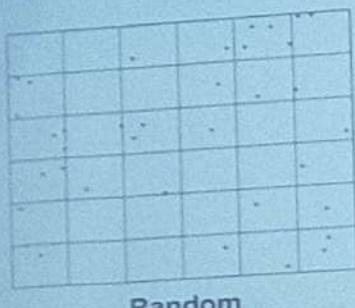
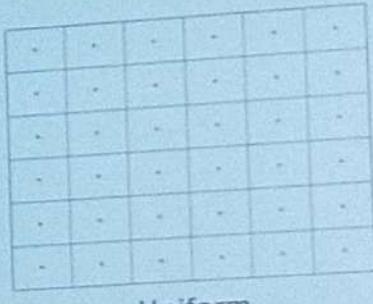


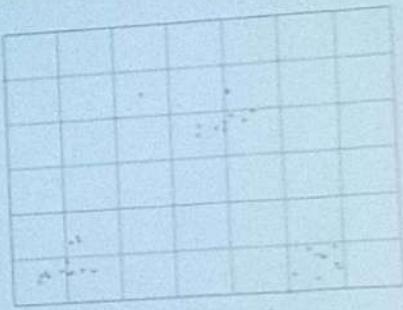
Fig. 6.4. Quadrat sampling method for population estimation.



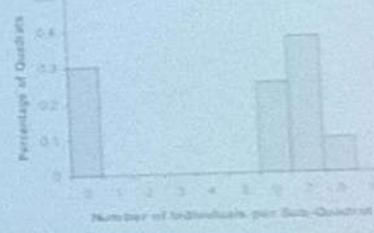
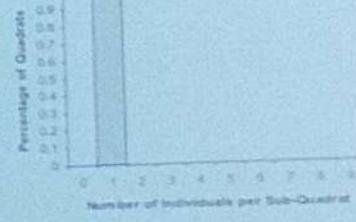
Random



Uniform



Clumped



While the above applies to local dispersion patterns within populations, it is important to remember that populations within a species also show dispersion patterns.

- Such populations often concentrate in clusters within the species' range.
- *Biogeography* is the study of factors that influence the distribution of a species over its range.

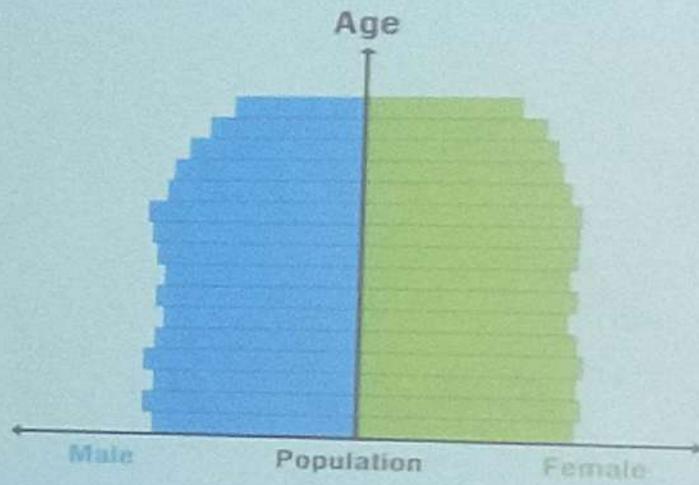
Demography is the study of factors that affect birth and death rates in a population

Demography is the study of the vital statistics affecting population size.

- ↳ includes relative rates of processes that add individuals to a population (birth, immigration) versus processes that eliminate individuals (death, migration).
- ↳ birth and death rates vary among population subgroups depending on age and sex.

Population Pyramids

Stable Pyramid



Population Pyramids

Constrictive Pyramid



Generation time is an important demographic feature related to age structure.

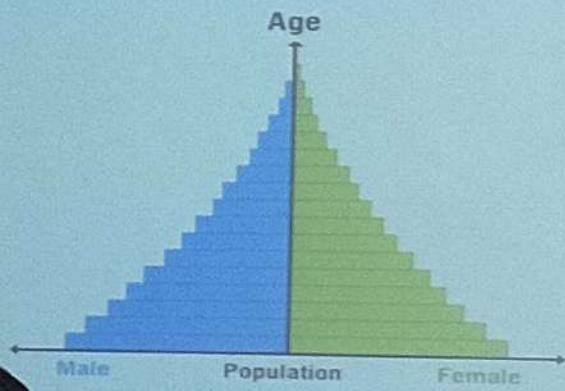
Generation time = The average span of time between the birth of individuals and the birth of their offspring.

- Strongly related to body size.
- A shorter generation time usually results in faster population growth, assuming birth rate is greater than death rate and all other factors being equal.

Another important demographic factor affecting population growth is the *sex ratio*.

Population Pyramids

Expansive Pyramid



A. Age Structure and Sex Ratio

Many populations have overlapping generations where individuals of more than one generation coexist.

- Exceptions include species in which all of the adults reproduce at the same time, then die (annual plants, many insects).

The coexistence of generations produces an age structure in most populations.

- Age structure = Relative numbers of individuals of each age in a population.
- Generations overlap when average life span is greater than the time it takes to mature and reproduce.
 - Every age group has a characteristic birth and death rate.
 - ⇒ Birth rate greatest for those of intermediate age.
 - ⇒ Death rate often greatest for the very young and very old.
 - In general, a population with more older, nonreproductive individuals will grow more slowly, than a population with a larger percentage of young, reproductive age individuals.

TABLE 55.1

Life Table for the 1978 Cohort of Cactus Ground Finch (*G. scandens*) on Isla Daphne

AGE CLASS (YEARS)	NUMBER ALIVE	SURVIVORSHIP ^a (%)	MORTALITY ^b
0-1	210	—	0.57
1-2	91	0.43	0.14
2-3	78	0.37	0.10
3-4	70	0.33	0.07
4-5	65	0.31	0.05
5-6	62	0.30	0.03
6-7	43	0.20	0.45
7-8	23	0.11	0.35
8-9	15	0.07	0.07
9-10	14	0.07	0.21
10-11	15	0.05	0.09
11-12	10	0.05	0.60
12-13	4	0.02	0.25
13	3	0.01	—

^aSurvivorship = the proportion of the original cohort (here, of 210 individuals) who survive to age x .

^bMortality ("death rate") = the proportion of individuals of age x who die before reaching age $x + 1$.

TABLE 55.2

Fecundity Schedule for the 90 Females of the 1978 Cohort of Cactus Ground Finch (Table 55.1)

AGE CLASS (YEARS)	FECUNDITY ^a (m)
0-1	0.00
1-2	0.05
2-3	0.67
3-4	1.50
4-5	0.68
5-6	5.50
6-7	0.69
7-8	0.00
8-9	0.00
9-10	2.20
10-11	0.00
11-12	0.00

^aFecundity = number of fledglings per female per breeding season.

Survivorship curves plot the numbers in a cohort still alive at each age. Organisms may exhibit one of three general types of survivorship curves:

1. Type I curves are flat during early and middle life and drops suddenly as death rates increase among the older individuals.
 - Associated with species such as humans and other large mammals that produce few offspring that are well cared for.
2. Type II curves are intermediate with mortality being more constant over the life span.
 - Seen in *Hydra*, gray squirrels, and some lizards.
3. Type III curves show very high death rates for the young followed by lower death rates after individuals have survived to a certain critical age.
 - Associated with organisms, such as oysters, that produce very large numbers of offspring but provide little or no care.

B. Life Tables and Survivorship Curves

Life tables describe how birth rates and death rates vary with age over a time period corresponding to maximum life span.

- Constructed by following the fate of a *cohort*, a group of individuals of the same age, from birth until all are dead or by using the age specific birth and death rates in a population during a specified time.

Sex ratio = The proportion of individuals of each sex found in a population.

- The number of females is usually directly related to the expected number of births.
- The number of males may be less significant since one male may mate with several females.
- In strictly monogamous species, the number of males is more significant in affecting the birth rate than in nonmonogamous species.

Even though life history traits vary widely, there are some basic patterns:

- Life histories often vary in parallel with environmental factors. For example, clutch sizes increase with latitude.
 - ⇒ Tropical birds lay fewer eggs than those in higher latitudes which reflects the number of offspring that can be successfully fed.
 - ⇒ Since daylengths are longer at higher latitudes than the tropics during offspring-rearing season, parent birds can gather more food and feed more offspring.
 - ⇒ The clutch size-latitude variation is also found in many mammals, lizards, and insects.

III. The traits that affect an organism's schedule of reproduction and death make up its life history

A. Variation in Life Histories

Natural selection, working over evolutionary time, results in traits that affect an organism's life history.

Life history = An organism's schedule of reproduction and death.

- Life histories are important in population ecology because these traits affect population growth over time.

- There is a diversity in life histories due to the varying pressures of natural selection.
- Some animal species hatch in one type of biome, migrate to another where they mature for several years, then return to the initial biome for a single massive reproductive effort, then die (i.e. salmon).
 - Other animal species hatch and mature rapidly in a single habitat, then have small reproductive efforts each year for several years (i.e. lizards).
 - Life history characteristics may vary significantly among populations of the same species or even among individuals within a population.

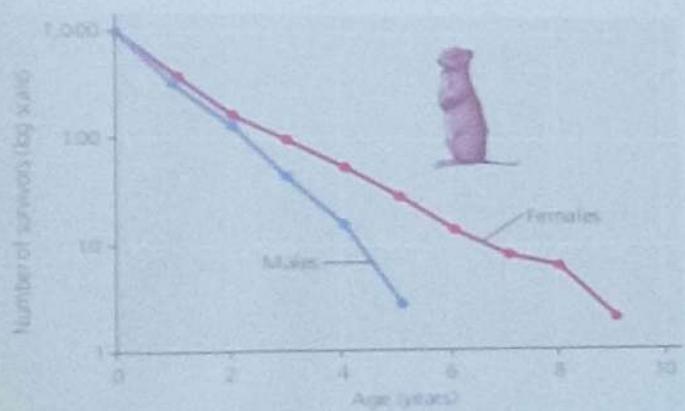


Figure 53.5 Survivorship curves for male and female Belding's ground squirrels. The logarithmic scale on the y-axis allows the number of survivors to be visible across the entire range (2–1,000 individuals) on the graph.

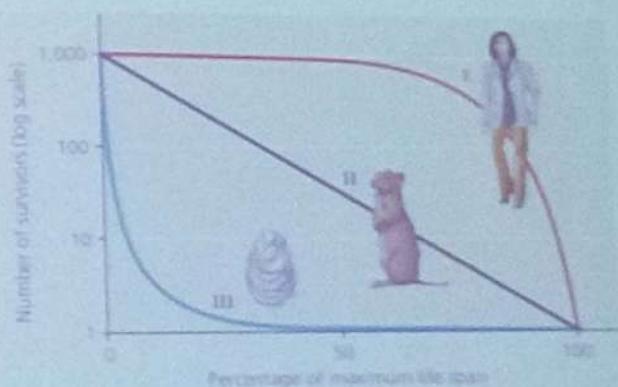


Figure 53.6 Idealized survivorship curves: Types I, II, and III. The y-axis is logarithmic and the x-axis is on a relative scale, so that species with widely varying life spans can be presented together on the same graph.

Many species exhibit curves between the basic types of survivorship curves and some have more complex curves.

- Great tits show a high mortality rate in young birds (Type III) but a fairly constant mortality (Type II) in adults.
- Some invertebrates show a "stair-stepped" curve with brief periods of high mortality during molts, followed by periods of lower mortality when the exoskeleton is hard (i.e. crabs).