Eusociality

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Photograph © Alex Wild 2003
Eusocial: True Sociality

Found mainly in two orders:

- Hymenoptera (some bees and wasps, all ants)
- Isoptera (all species)
Eusocial Insects

Features (by definition):

1. Overlap of generations
2. Division of labor (Caste system) – not all individuals reproduce
3. Cooperative rearing of young
Eusocial Insects

May also show

- **Trophallaxis** (Ritual feeding)
- Complex chemical communication (pheromones)
- Nest
  - Often with controlled atmosphere
- Specialized reproductive biology
  - Production of new colonies vs. production of new individuals
- Rare (2% of species), but highly successful (some tropical areas >3/4 of biomass)
Eusociality

- Some individuals reduce their own lifetime reproductive potential to raise the offspring of others.
How did eusociality evolve?

- **Mystery**: not in an individual’s self interest to give up reproducing!

Different theories: Controversial

Hamilton (1964): kin selection (inclusive fitness)
- Haplodiploid reproduction (all Hymenoptera, also eusocial thrips)

- **Kin selection** refers to apparent strategies in evolution that favor the reproductive success of an organism's relatives, even at a cost to their own survival and/or reproduction.
They’re of the same blood: The importance of relatedness

• Sisters are more related to each other than they are to their own mother or father
How did eusociality evolve?

• Group selection
  – Formation of a group
  – Persistence and cohesion of the group, defensible nest
  – Spreading eusocial alleles
  – Spreading of others traits that favor the group
  – Natural selection acting on a group
Mechanisms of Social Organization

Social organization by social insects was long held as an example by the aristocracy and various religions as a model to how human societies should be organized.
Mechanisms of Social Organization
Centralized

- Following a leader
- Using a plan, blueprint or recipe
- Using a template or mould
Insect societies are well organized, but how do they achieve this?

Proverbs 6: 6-8- “Go to the ant thou sluggard: consider her ways, and be wise. Which having no guide, overseer of ruler, provideth her meat in the summer, and gathereth her food in the harvest”.

In insect societies no one is in charge.
Mechanism of Social Organization
Self–organization or De-centralized

• Global pattern of organization arises from the interactions of many individuals whom follow simple rules in response to local conditions. No one individual is in charge.

• Ex: cells in a multicellular organism, grains of sand in a sand dune, social insect colonies
Activity
In what ways can sociality benefit insects?
Insect sociality

• Benefits of sociality:
  – Utilization of large and more diverse resources
  – Group defense against predators
  – Existence as perennial, long-lived organisms
“Super-organism”

- Intake resources
- Waste disposal
- Defense
- Reproduction
- Environmental control

They use **social design** to solve ecological problems normally faced by single organisms—origin of the concept of “super-organism”
Who are the bees in your colony?
Sex determination

Unfertilized eggs (1n) → Fertilized eggs (2n) → Males (2n)

Fertilized eggs (2n) → Fertilized eggs (2n) → Females (2n)
Sex Determination

• If an egg is heterozygous at the sex loci = Become a female
• If an egg is homozygous at the sex loci the individual will be a diploid drone
• If the egg is unfertilized (therefore haploid) the individual will become a viable haploid drone
Mating genetics

Spermatheca full of stored sperm
(actually 4-7 million sperm)

Leads to a number of subfamilies in the colony

(actually about 17 drones)
Basic Biology

Colony genetics

Leads to a number of subfamilies in the colony

6 subfamilies present in this hive
Haplodiploidy

• **Haplodiploidy:** Viable drones come from unfertilized eggs, females from fertilized eggs
Biology of the Colony
Swarming
Colony fission: natural swarming

Splitting is managerially equivalent to swarming: the natural process by which colonies reproduce

- Swarming has been shown as an acquired evolutionary technique that reduces pests and diseases within honey bee populations
- Occurs in mid to late spring when bee populations are high and flowering is more intense
A Cavity nester

- Location dependent on amount of available cavities and the ability to thermoregulate
Thermoregulation
Current *Apis* species distribution
Bee-dependent crops account for $47.1 billion every year, of which $14.6 billion is attributable to honey bee pollination.
Your produce choices with bees

Your produce choices without bees
Communication

- Honey bees are eusocial
- Prof von Frisch discovered their communication basics
- A bee discovers a food source….
  - she returns home to tell her sisters
  - where it is, how far, & how good!
Round Dance

Quick short steps in narrow circles
On beeswax comb

Food close

Odor & taste clues

Richness clues
Wagtail Dance

Bee makes ½ circle, straight run while waggling Abdomen then ½ circle again

Distance
Direction
Odor & taste clues
Richness clues
Wagtail Dance

From Gould & Gould 1988
Taste and smell

- The number of dancing bees and the frequency of dance can relay quality and quantity of resource
Dialects

• Different subspecies have different variations of the dance
• Different dances for different distances
• Different subspecies have trouble communicating location to one another
Colony Communication
# Pheromones of the Queen Honey Bee

<table>
<thead>
<tr>
<th>Pheromone</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queen substance (QMP)</td>
<td>mandibular glands</td>
</tr>
<tr>
<td>Foot-print pheromone</td>
<td>Arnhart (tarsal) glands</td>
</tr>
<tr>
<td>Tergal pheromone (abdominal)</td>
<td>Tergite glands</td>
</tr>
<tr>
<td>Feces pheromone</td>
<td>Hindgut</td>
</tr>
<tr>
<td>Egg marking pheromone</td>
<td>Dufor’s gland?</td>
</tr>
<tr>
<td>Queen attractant scent</td>
<td>Koschevnikov gland</td>
</tr>
<tr>
<td>Queen cell pheromone</td>
<td>immature queen / cell</td>
</tr>
</tbody>
</table>
Queen Substance

Source: Mandibular glands

Primary component:
9-oxo-trans-2-decenoic acid

Mixture of 5 compounds; blend important
• Virgins and mated queens have different QMP profiles
Queens with more mates have more attractive QMP profile
Queen Substance Dispersal

Queen pheromone
Retinue Formation

- Mandibular gland pheromone complex
  - Mixture important, single components do not have activity
Queen Inhibition of Queen Rearing

- Queen mandibular gland complex - major inhibitor (exception)
- Additional pheromone from tergite glands may help suppress queen rearing
- Possible “fecundity” signal from young brood
Inhibition of rearing replacement queens
Sex attraction
Swarm Stabilization
Stimulation of foraging/brood rearing
Participates in suppression of worker ovaries
Egg Pheromone

- Queen produced

Function: discrimination of queen-laid versus worker-laid eggs

Aid to worker policing of worker-laid eggs
Queen Cell Pheromone

- Present on queen pupae: methyl linoleate, methyl linolenate, methyl oleate
- Functions:
  - Recognition of queen cells
  - Serve as part of a feed-back control system governing the production of queen cells
Worker Pheromones

• Orientation
  – nasonov gland

Mixture of 7 terpenoids: E- & Z- citral, nerol, nerolic acid, geraniol, geranic acid & farnesol
Worker pheromones

- Orientation
- Alarm
  - worker mandibular gland
    - 2 heptanone
  - worker sting gland
    - Iso-pentyl acetate
Worker Pheromones

- Orientation
- Alarm
- Trail pheromone
- Brood pheromone
- Beeswax comb
- others
Hive Odor

Guard bee
Age based polyethism

Worker bees: behavioral development

Days since emergence

2 - 10
11 - 20
21 - 35
Division of Labor in Worker Bees

Forage for nectar, pollen, water

Just emerged!

Clean out dirty honeycomb

Dies at 5-7 weeks

3 weeks

Remove corpses

1 week

Feed larvae

Build honeycomb

2 weeks

Guard the hive

Receive food from incoming foragers
Colony Requirements

- Nectar
- Pollen
- Water
- propolis
From Nectar to Honey
From Nectar to Honey

- Nectar is 80% water, whereas honey is only 19% water
- To make 1 pound of honey, a colony of bees collects nectar from over 1 million flowers
Vertical stripes are very slimming.