Insect senses: how to hear with your legs and taste with your feet (yum!)
INSECT SENSES

PART I: The obvious:

Vision
Hearing
Smell

PART II: The less obvious:

A sense of time and direction

PART III: Smell revisited
INSECT VISION

Ocelli
• simple lense eyes,
• good for contrasts
• not image forming
• many insects have lost them

Compound eyes (= sum of 100s-1000s of ommatidia)

Insects see with their eyes!!!
APOSITION eye

- pigment cells - prevent the same light wave from being seen by multiple ommatidia
- ommatidium
- with rhodopsin
- absorbs photons and generates AP
- corneal lens
- crystalline cone
- rhabdom
- with rhodopsin
- absorbs photons and generates AP
- nerve cells
- basal lamina
- axons
SUPERPOSITION

eye

pigment cells!!
CONSEQUENCES???

APOSITION eye

- high resolution
- low sensitivity, i.e. needs much light
- only good for day-active insects

SUPERPOSITION eye

- low resolution
- high sensitivity
- only good for night-active insects

What about crepuscular insects?
INSECT SENSES

PART I: The obvious:
- Vision
- Hearing
- Smell

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PART III: Smell revisited
Insects see with their eyes, but do they hear with their ears?

What, really, is an insect ear?

To understand how insects hear, ironically we first need to understand how they breathe...

(no lungs, no haemoglobin, instead a bunch of inter-connected tubes called trachea!)
Insects differ in the region of their hearing organ.

But regardless of placement it is always part of the tracheal system!!
Insects differ in the region of their hearing organ. But regardless of placement it is always part of the tracheal system!!

So why is it good to have two ears, and not just one?
INSECT SENSES

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Insects use smell to detect many different things:

- Food
- Nest
- Partners
1a) General Definition

- Chemical substances released by one individual and received by another individual of the same species

- Once received pheromones trigger the expression of a particular behavior or developmental program
PHEROMONES

3) Reception and Recognition – *sensory apparatus*

- insects use chemoreceptors (**olfactory sensilli**) to receive and recognize pheromones
  → consist of:
  a) sensory neuron that projects dendrites into cuticular outgrowth with pores
  b) trichogen cell that provides the shaft for the neuron
  c) a tormogen cell that provides an anchor or socket

**Steps in odor recognition**

1) molecules enter sensillum through pores

2) bind to olfactory binding proteins (OBP) and get transported through the pore tubules to dendrites

3) OBP-molecule complex recognized by particular dendrite-surface proteins

4) causes a local change in membrane potential

5) if enough of the same molecules affect the dendrites this generates action potential which is then relayed to the brain
PHEROMONES

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ensure specificity

What about sensitivity?
4b) Sensitivity - continued

Example: *Bombyx mori* (Saturniidae)

- 2 large, feathery antennae, 17 000 total 3000 pores/sensillum; = 45 Mill. pores/moth
- main purpose: detection of female sex pheromone *Bombycol*
- discovered by Adolph Butenandt 1957
- purified *Bombycol* using 1 000 000 cocoons
- after many extractions these yielded 6.4 mg *Bombycol*
- tested attractiveness of pure *Bombycol* using flutter response assay
- males were able to recognize concentrations as low as $1 \times 10^{-12}$ microgram/ml.
INSECT SENSES

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**Example:** Honey bees

**Background:**
- Honey bees rely exclusively on pollen and nectar as food resources.
- Individual forager bees identify forage sites, then return to nest and return with additional nest mates.
- When initial forager is prevented from returning to food source, its nest mates still appear quickly at the new forage site.

**Conclusion:** somehow information is exchanged in the hive that allows nest mates to locate new forage site.
Background:
• we now know that bees use the waggle dance to communicate:

(a) quality of forage site

(a) distance away from nest site

(a) direction relative to current position of the sun
Dance language of honey bees

*Components of the waggle dance:*

(a) dance consists of figure-8 type dance with; bees buzz their wings and waggle abdomen during straight part

(b) intensity of dance (rounds/time) and intensity of buzzing on straight part indicate quality of forage site

(c) length of straight part indicates distance away from hive

(d) angle and direction of straight part relative to gravity indicate angle and direction of forage site relative to the sun when viewed from the hive
Dance language of honey bees

Communicating direction of forage site relative to the sun
Communicating direction of forage site relative to the sun

This also works on a cloudy day when the sun is not visible! How??

Bees (as well as many other organisms) can see polarized light and orient accordingly
Dance language of honey bees

How precise is it?

Experiment 2, $\tau = 529$ ms
Experiment 4, $\tau = 441$ ms

Distance, $d$ (m)

Mean waggle duration, $\tau$ (ms)
Dance language of honey bees

But then: a simple experiment with an unusual outcome (Lindauer 1960)
Dance language of honey bees

Locality 1, Day 1, Afternoon

Locality 2, Day 2, Morning

predicted

observed
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A simple and highly reliable experiment with termites...
What you need

- A cheap ball pen, blue
- A piece of paper, clean
- A local termite, alive
What you should do

• Using the blue pen draw a circle on the paper

• Carefully release the termite in the center of the circle

• Carefully watch the termites behavior
The idea behind this exercise...

- The termite will soon do something that will make you think

- It does the same to students, school kids, anyone who sees this for the first time; you can’t help it

- If provides a wonderful opportunity to introduce the scientific method, generate hypotheses, and go test them...
**TRAIL-PHEROMONES**

- widespread in social insects
- use trail pheromones to mark trail to food sources or nest entrances
- released by specialized glands and dipped onto substrate
- most commonly studied in ants and termites
- also in the most primitive bees (Melliponinae) (sweat bees; have to land and deposit their pheromone on plants along their flight path).

Honeybees no longer use trail pheromones.
How do honey bees tell their colony mates where to go?
SEX-PHEROMONES

A) Attraction pheromones (long range)
   Example: Bombycol, *Bombyx mori*

B) Courtship pheromones (short range)
   Example: Danaidone, *Danaus gilippus*
   Queen butterfly

   - released by males via a pair of glands located at the tip of their abdomen
   - resembles structurally a class of chemical compounds found in certain flowering plants and known as **pyrrolizidine alcaloids**
   - males cannot produce Danaidone themselves and instead ingest alcaloids from larval host plant and chemically modify them

!?? - females prefer males with high alkaloid concentrations and females have more offspring survive if mated to a male with high alkaloid concentrations in pheromone
SEX-PHEROMONES – cont.

B) Courtship pheromones (short range)
Example: Danaidone, Danaus gilippus

- turns out that males convert only a small portion of the alkaloids they ingest to danaidone
- ~80% of alkaloid load stored in small sacs in their reproductive accessory glands.
- during copulation male transfers toxic alkaloids from glands to the female
- female in turn incorporates alkaloids into egg case
- egg predatory insects avoid eggs that contain high alkaloid concentrations