Lecture 5:
The pheromone sub-system

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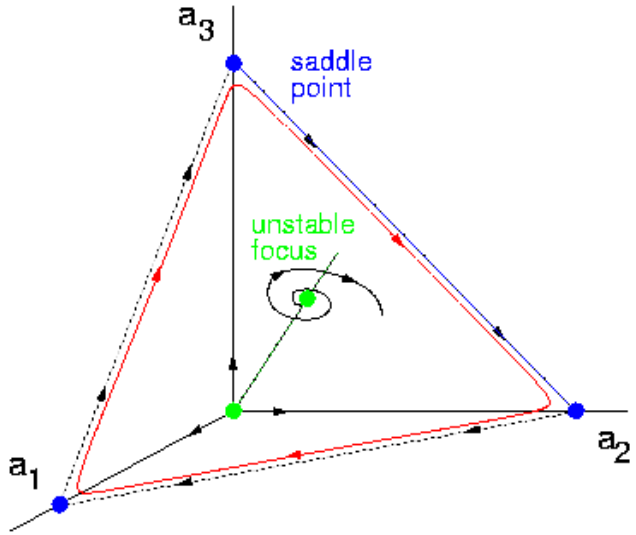
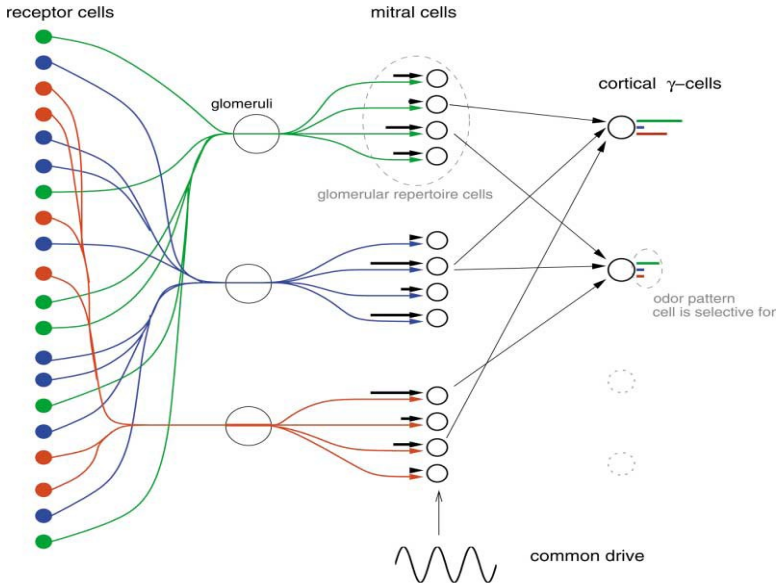
Last time ... general olfactory system

Winnerless competition



Hopfield's model of olfaction



- This was all about the general olfactory system
- Today: Pheromone sub-system

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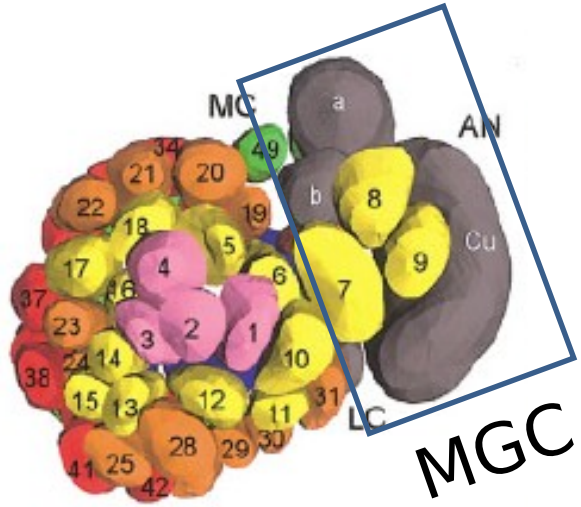
Role of pheromones

- Pheromones are substances that animals secrete to communicate with each other
- Examples
  - Pheromone trails laid by ants
  - Pheromones in urine to mark territory
  - Sexual pheromones to communicate mating status
  - Sexual pheromones to attract mates
  - ...

Pheromone sub-system: Anatomy

Pheromone sub-system:
Macro-glomerular Complex (MGC)

General antennal lobe



MGC area

In insects there are typically 2-3 large glomeruli exclusively dedicated for pheromone processing

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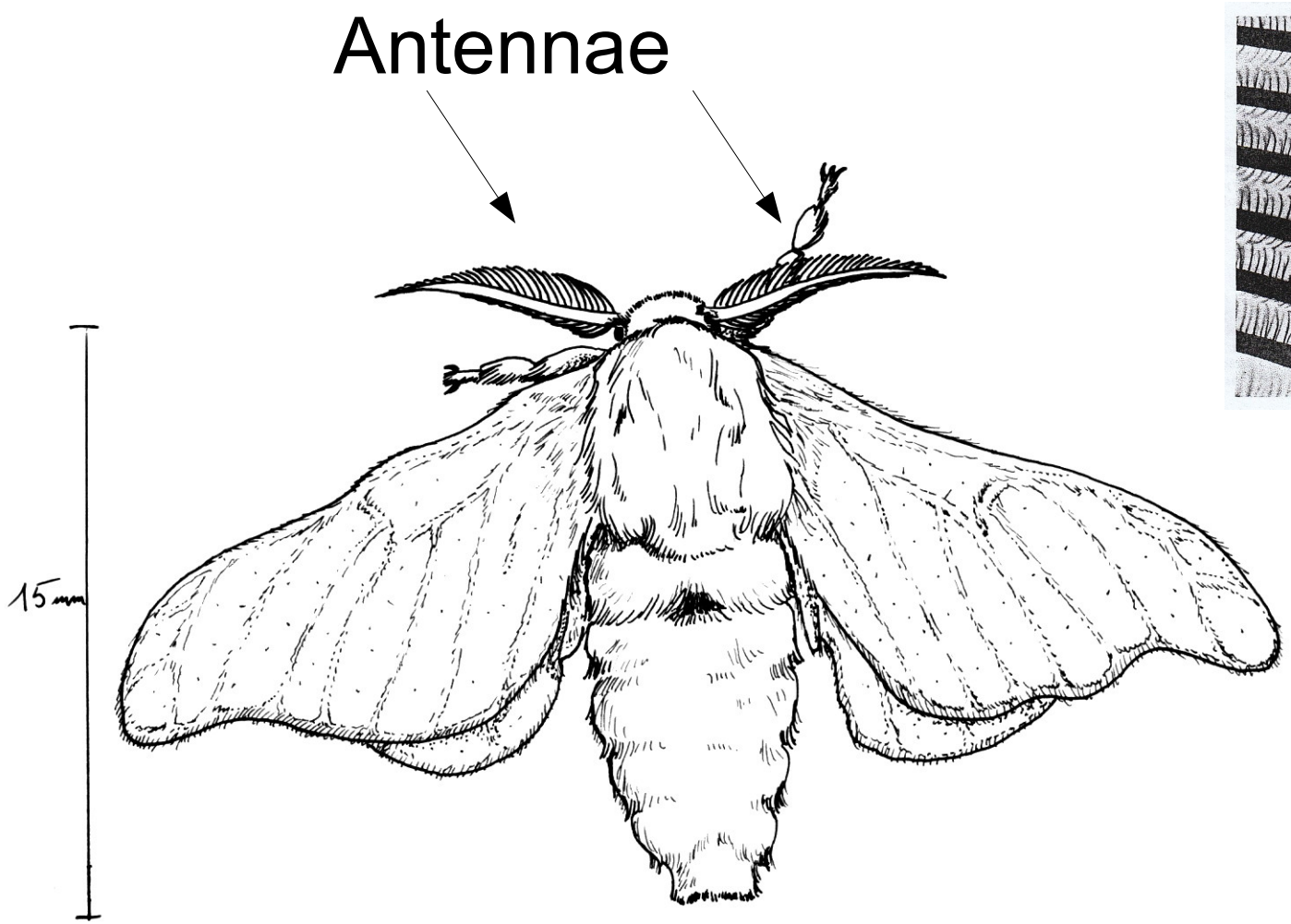
Pheromone sub-system in moths

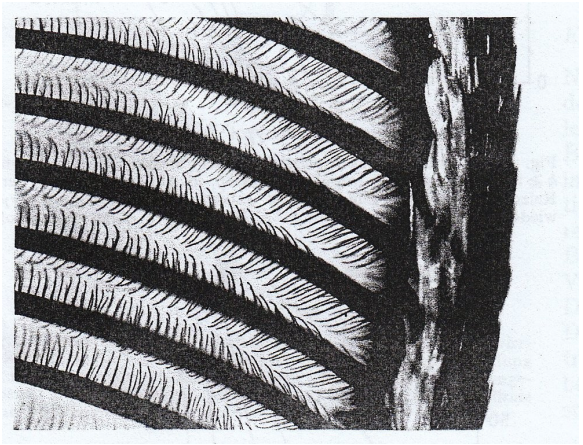
- Here I will concentrate on the pheromone system of moths
- Pheromone is secreted by females to attract males
- Males can smell the pheromone at distances of up to 2-3 miles
- Pheromone blend consists of several chemicals (components), in a typical ratio
- Related (but distinct) species may use the same chemicals but in a different ratio (!)

Pheromone subsystem is different

- General olfactory system
  - ORN broadly tuned
  - One ORN type – one glomerulus
  - Need to recognize pure odors, mixtures, concentrations
- Pheromone sub-system
  - ORN very narrowly tuned to 1 chemical
  - One ORN type – one glomerulus
  - Need to recognize one specific mixture of pheromone components

Bombyx Mori (Silk Moth)





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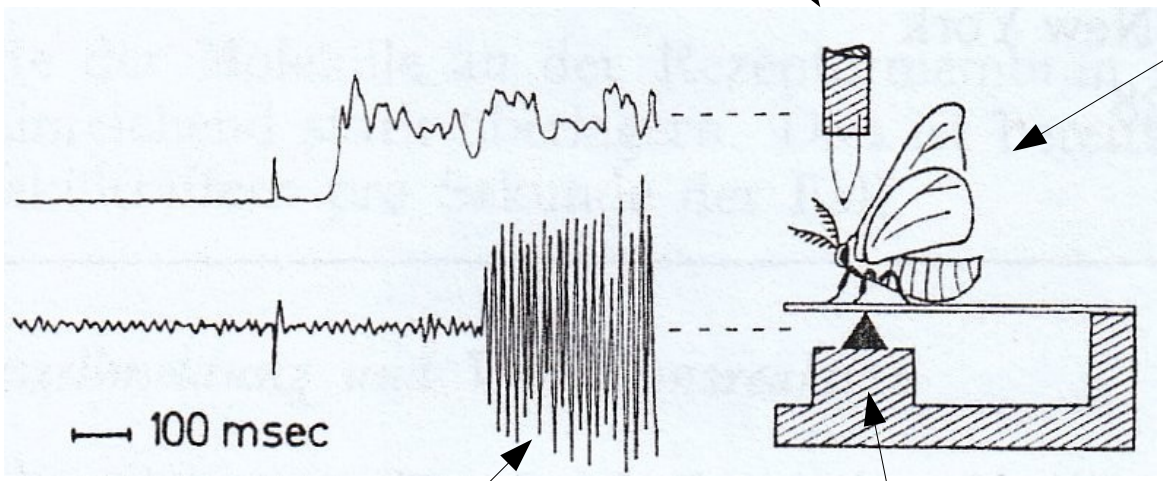
Classic results on Bombyx Mori

In the following we will have a look at classic results from

Kaissling K-E and Priesner E, “Die Riechschwelle des Seidenspinners”, Die Naturwissenschaften **57**(1): 23-28, 1970.

Type of experiments: Behavioral

Thermistor to register air flow



Male Bombyx Mori

Recorded wing movement

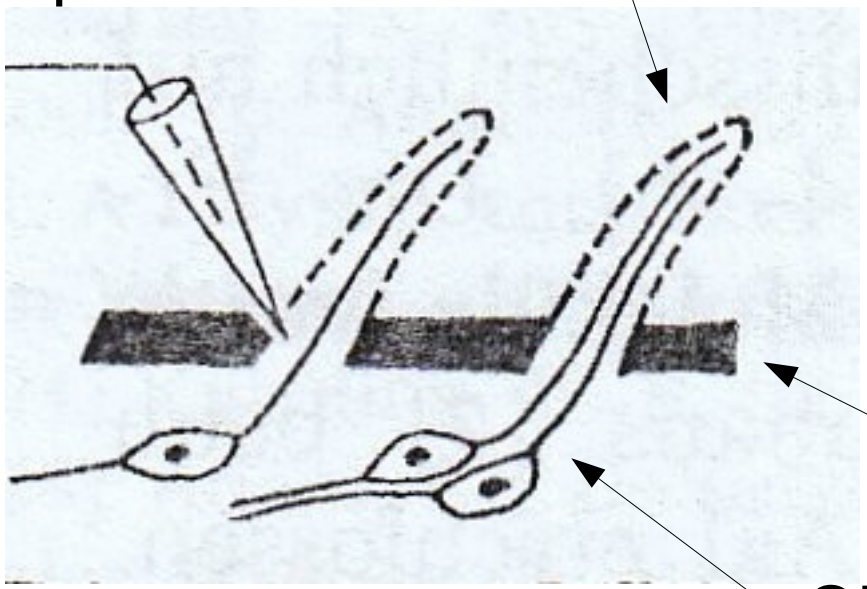
Pressure sensor (from an LP player)

Kaissling & Priesner

Type of experiments: Electrophysiology

Sensillum

To Amplifier



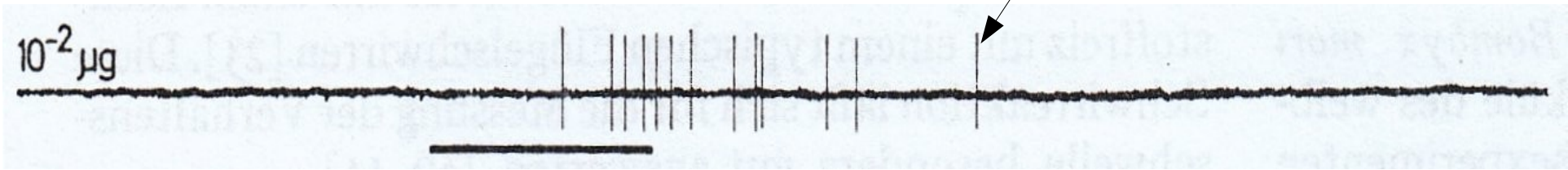
Extra-cellular recordings

Only spikes visible

Cuticle

ORN

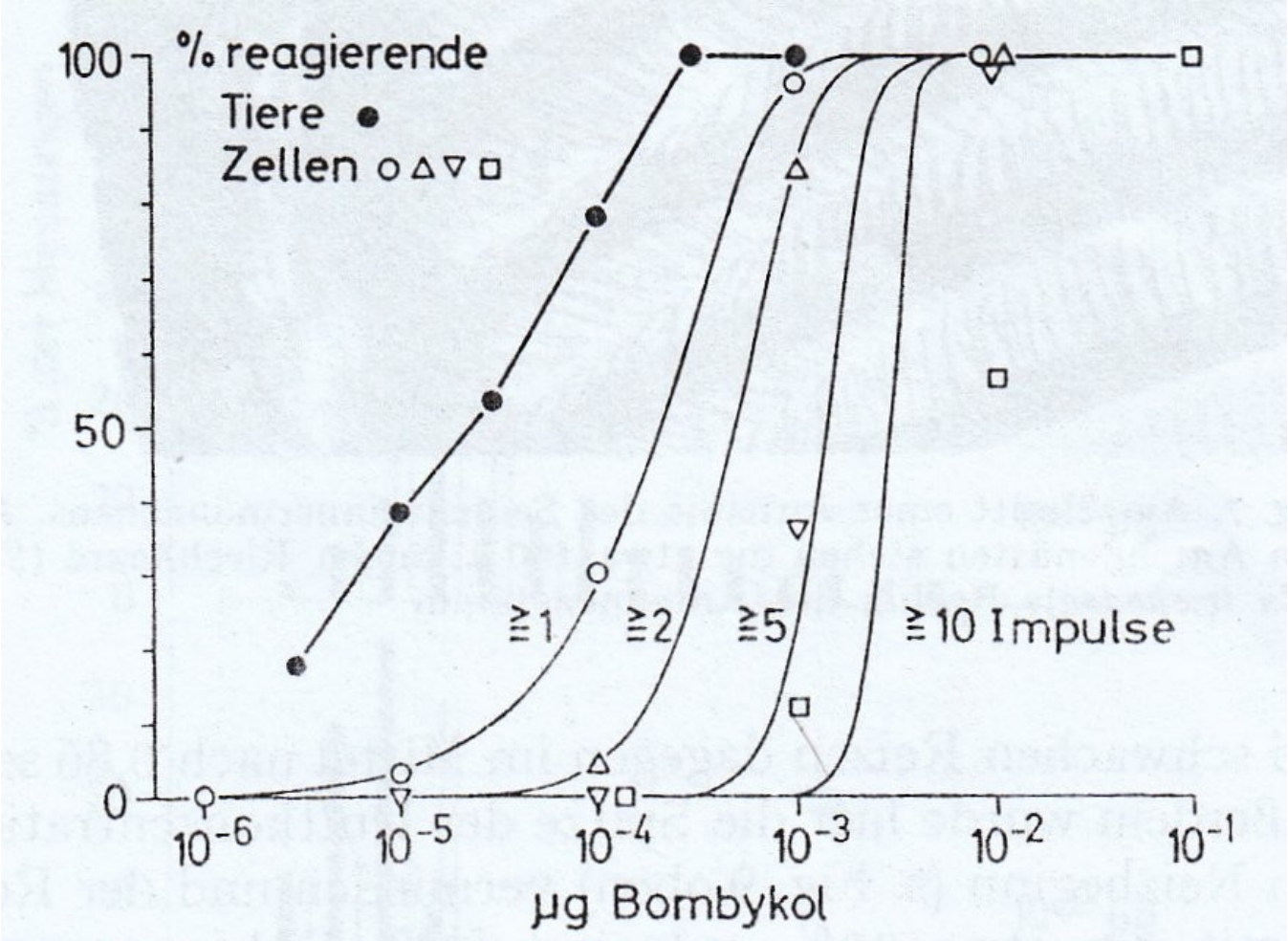
ORN spikes



Stimulus

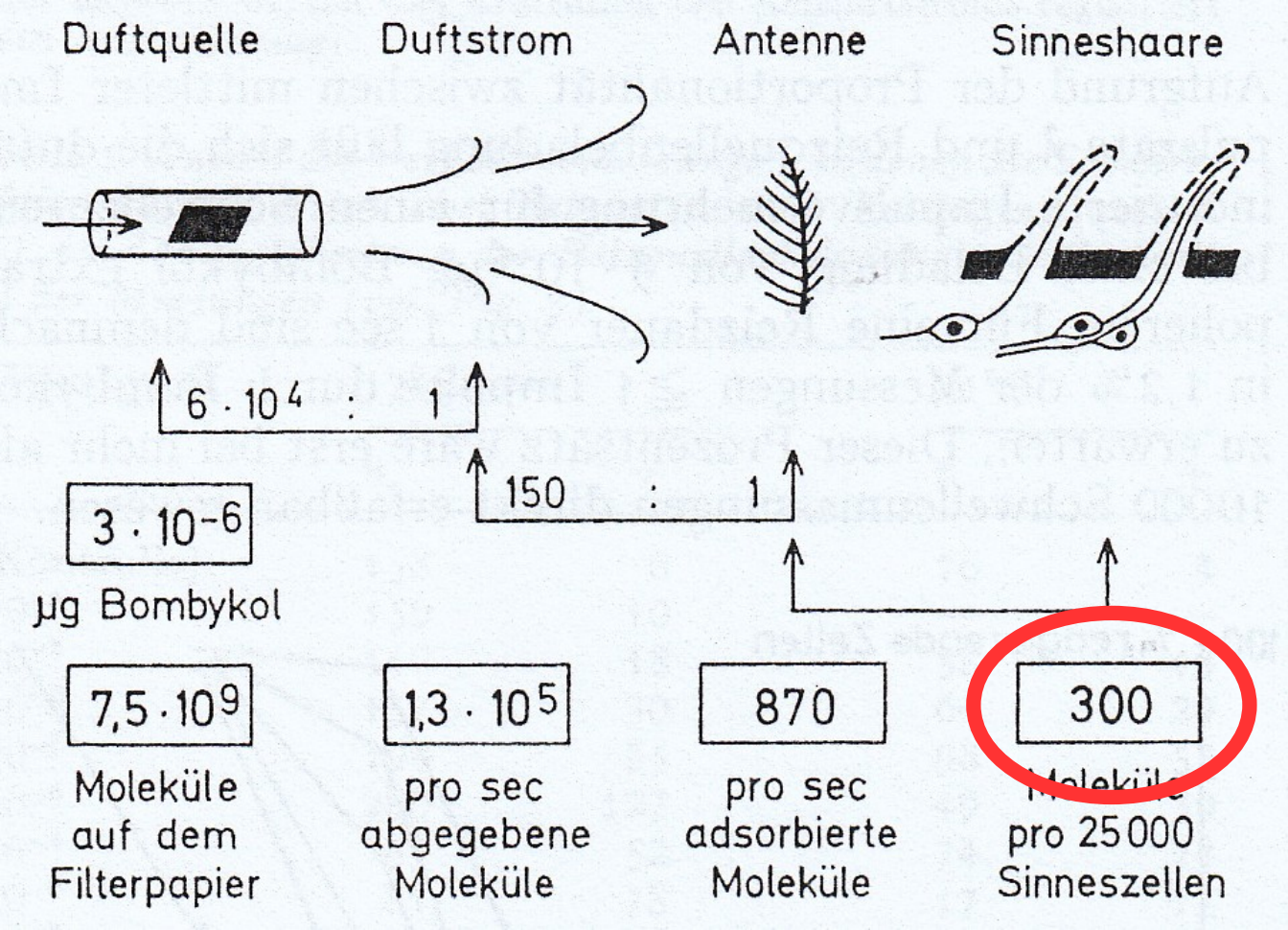
Kaissling & Priesner

Sensitivity (behavior and ORN response)



Kaissling & Priesner

Analysis with radio-actively labeled pheromone



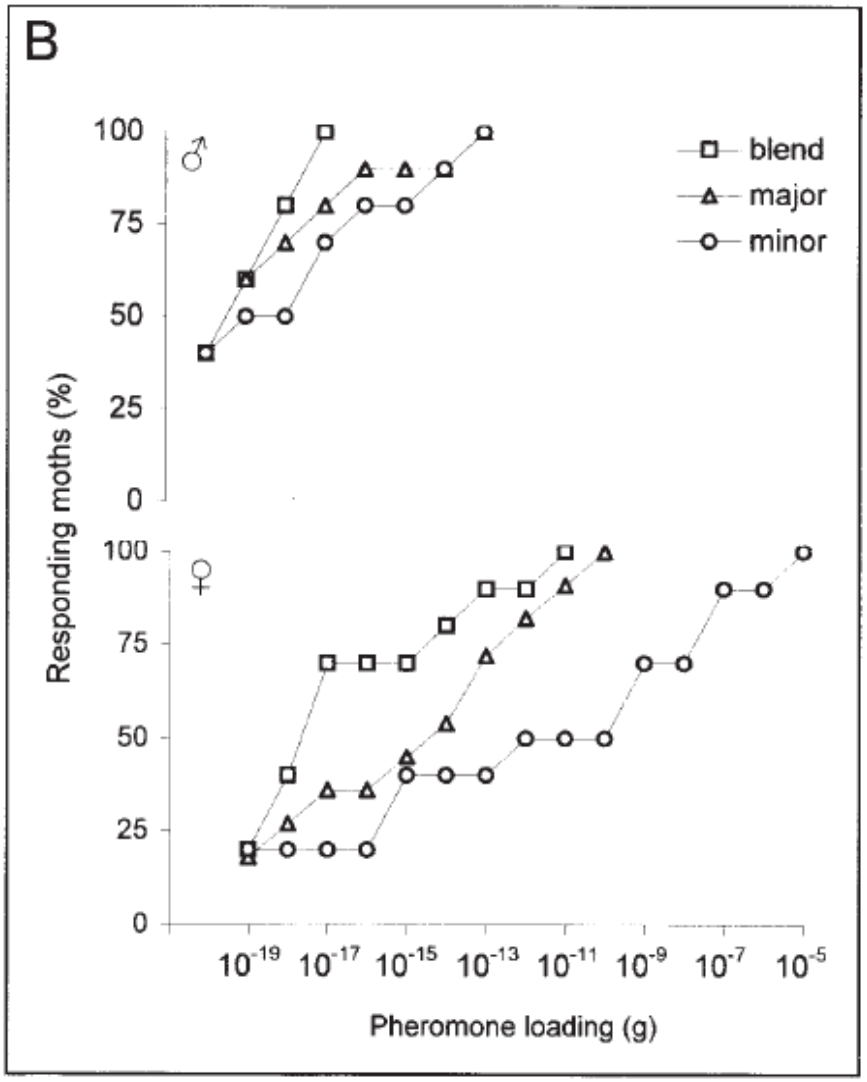
Kaissling & Priesner

More recent study

Angioy AM et al. “Extreme Sensitivity in an Olfactory System”, Chem Senses **28**:279-284 (2003)

- Similar experiments but measuring the heartbeat of the moths (rather than the actual behavior)
- Experiments on *Spodoptera Littoralis* (cotton leafworm)

Results



Male moths seem to respond from
$< 10^{-18}$ g (10^{-9} ng);
6 molecules on antenna (!)

(Kaissling: $3 \cdot 10^{-3}$ ng;
300 molecules on antenna)

Angioy et al, 2003

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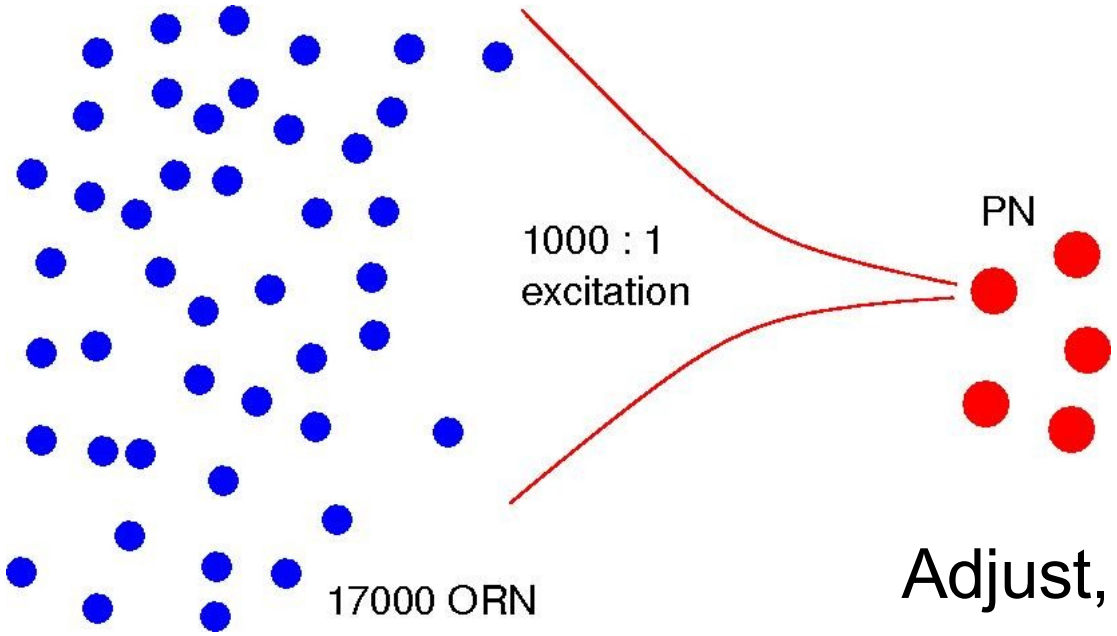
Sensitivity analysis

- Is the convergence of ~20000 ORN to less than 100 PN sufficient to explain response threshold at 300 molecules?

Simple statistical model:



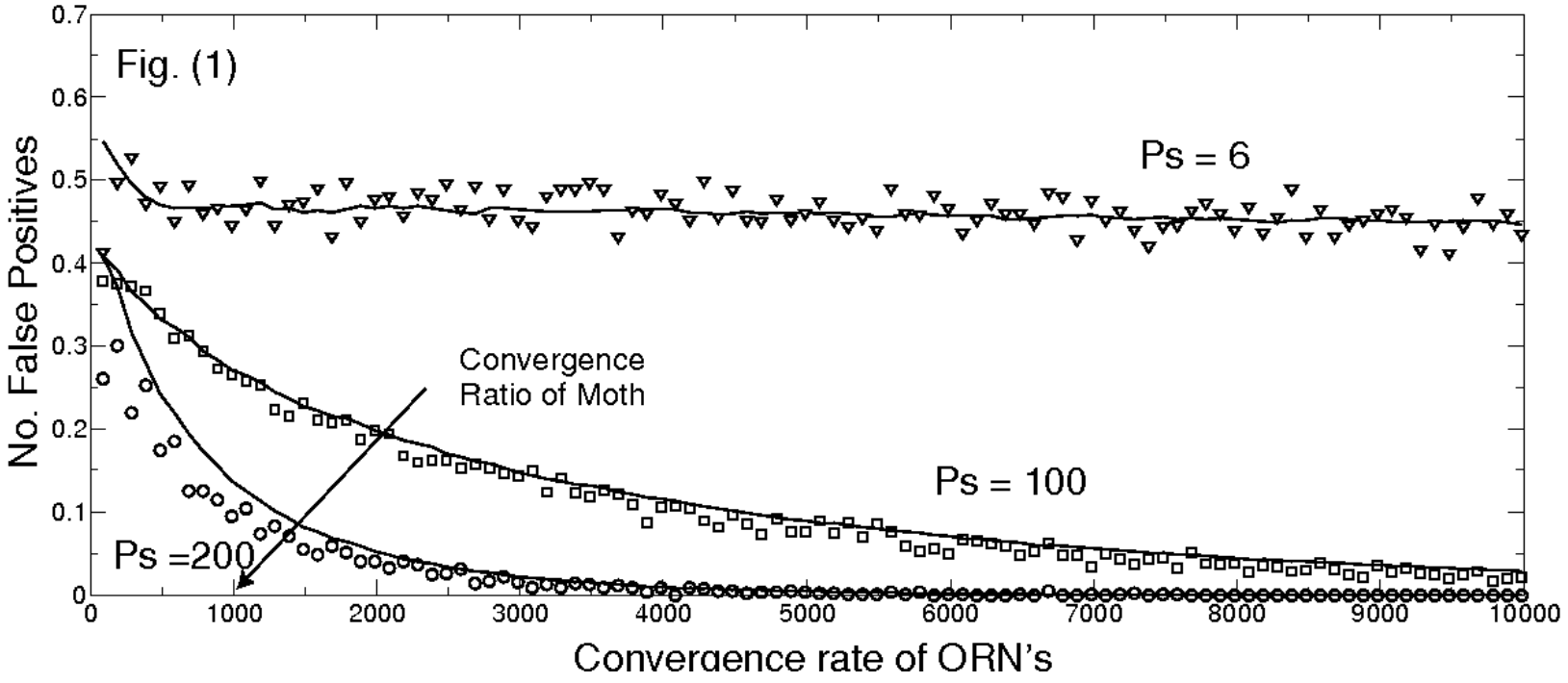
1600 spikes/s at baseline

1600+P_s spikes/s with pheromone

Adjust, such that 50 % response

Result on convergence sufficiency

Calculating the number of false positives:



Dr. Chris Buckley (Sussex)

http://www.informatics.sussex.ac.uk/research/projects/PheroSys/

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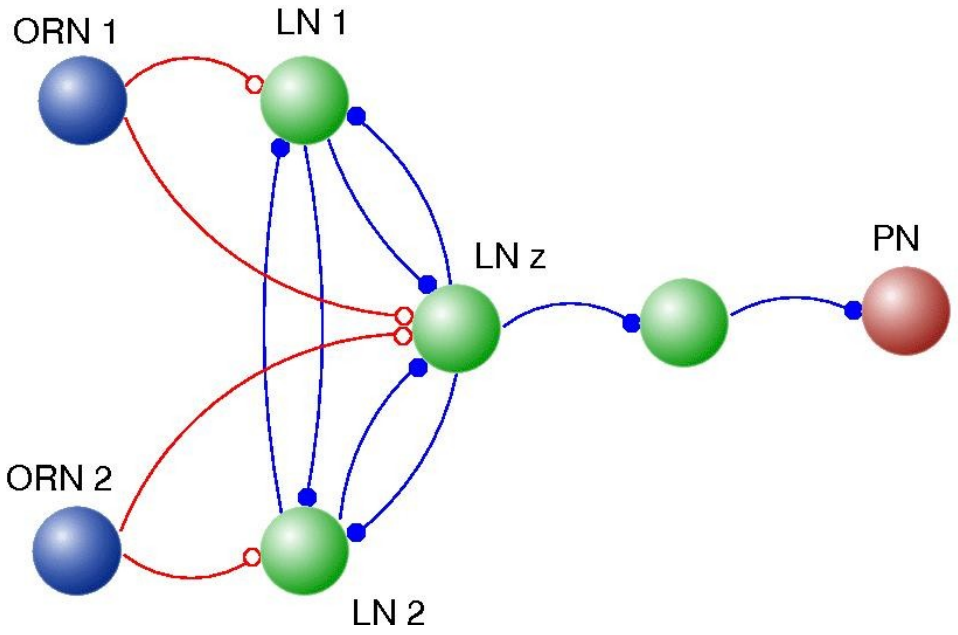
Conclusion so far

- s convergence enough to explain 200 molecule threshold? - maybe
- Is convergence enough to explain 6 molecule threshold? - no!
- ... to be continued

http://www.informatics.sussex.ac.uk/research/projects/PheroSys/

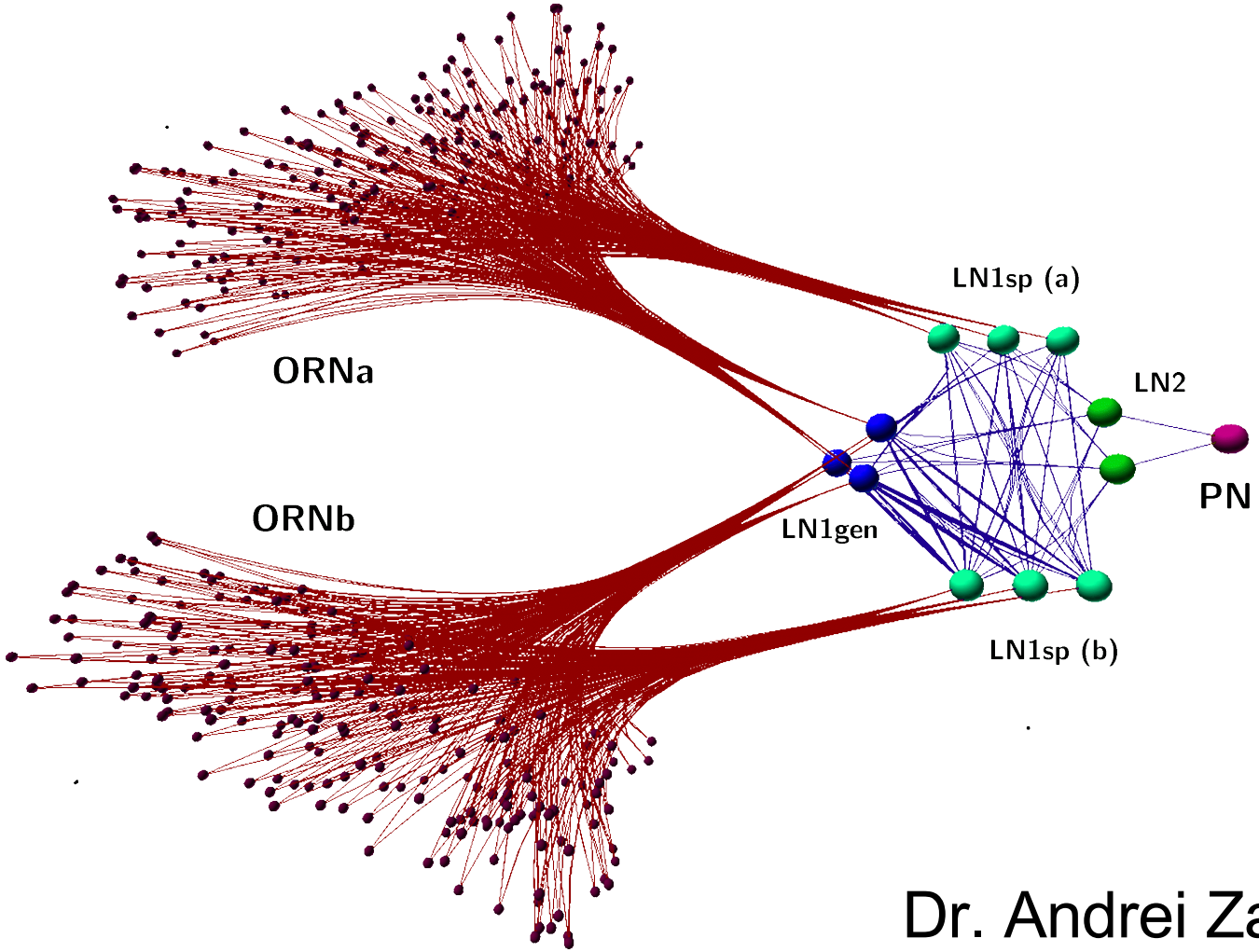
Ratio coding

- It is essential that moths can recognize the correct ratio over a large range of different concentrations
- In principle, this can be solved by winner-take-all competition, e.g.



See, e.g. Kwok YC, Encoding of Odor Blends in the Moth Antennal Lobe, PhD Thesis, University of Leicester, 2007

HH based model



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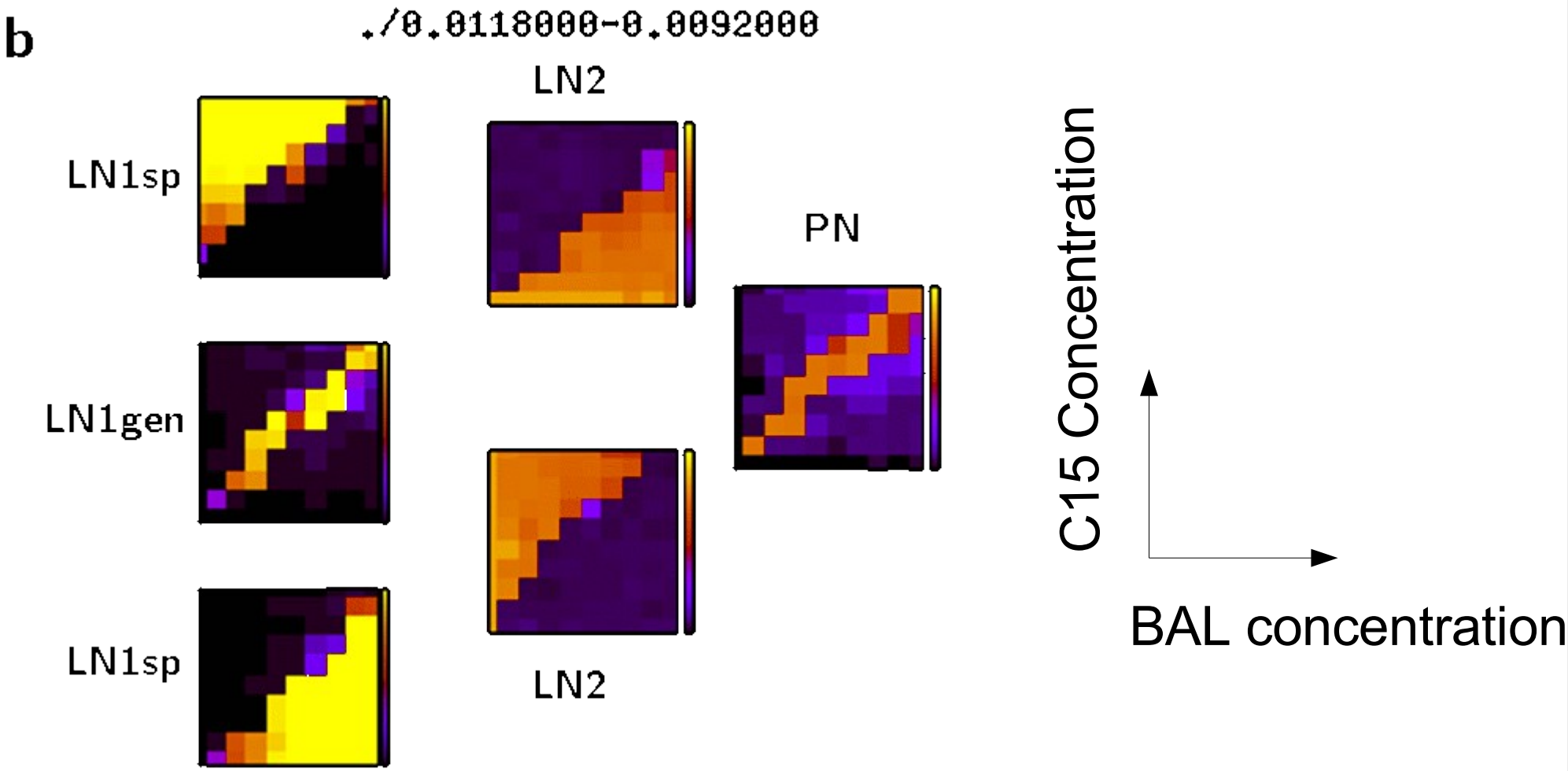
Preliminary Results



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Ongoing work

- Optimize model with automated parameter estimation
- Analyze emerging synchronization phenomena
- Different ratios
- Generalization to multiple ratios

http://www.informatics.sussex.ac.uk/research/projects/PheroSys/

Discussion

- Existence of human sexual pheromones still debated
- Warning: Perfumes that promise to contain pheromones draw typically on pig pheromones
- Note: If human pheromones exist, it is still unclear what role they may play: It is unlikely that it is for males to find females like in moths ...