Convergence in the sex pheromone pathway

From statistical analysis to modelling

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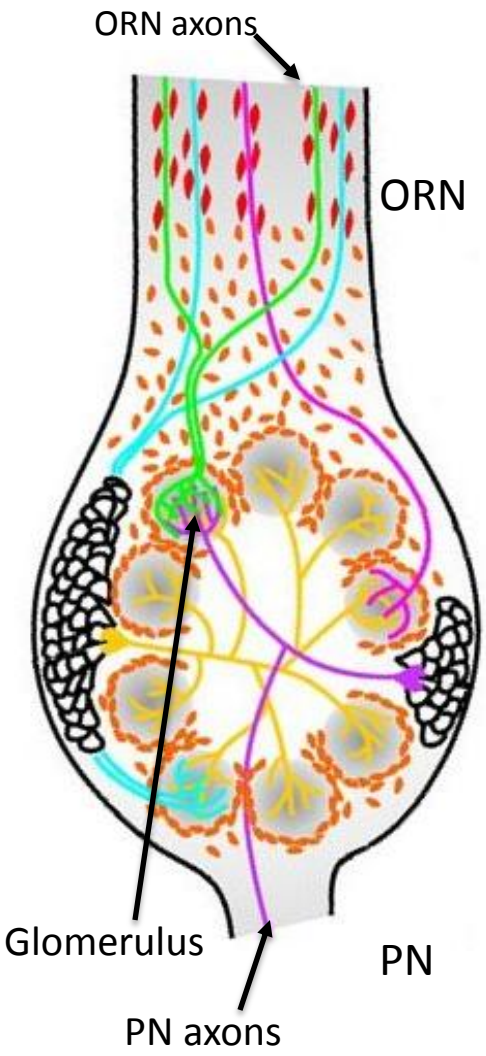
Experiment: David Jarriault & Antoine Chaffiol

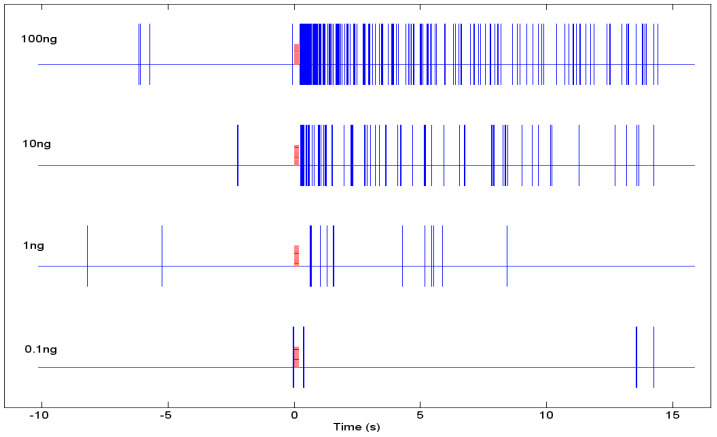
Insect: *Agrotis ipsilon*

Pherosys days 03/02/10

Input & output are analysed in parallel

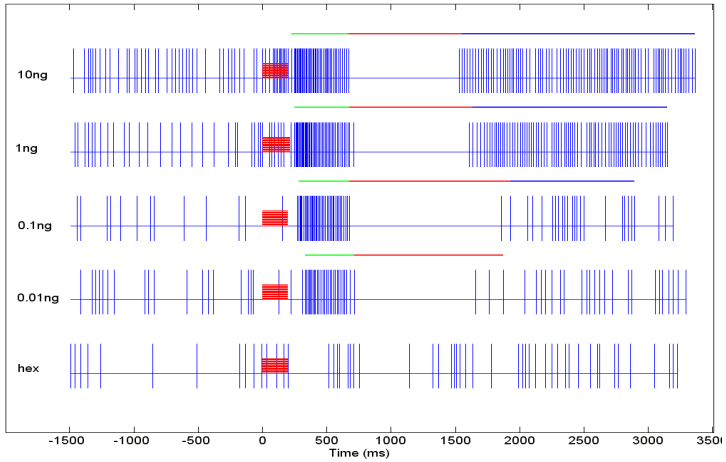
Major compound of sex pheromone: Z, 7-dodecen-1-yl





Tonic response

What is the relation input/output in the cumulus?



Phasic response:
-excitation
-long lasting inhibition

suite

Aims of the study

- Build a model of ORN population connected to cumulus:

- Statistical analysis of single ORNs

- Computational model of ORN population

- Build a model of cumulus:

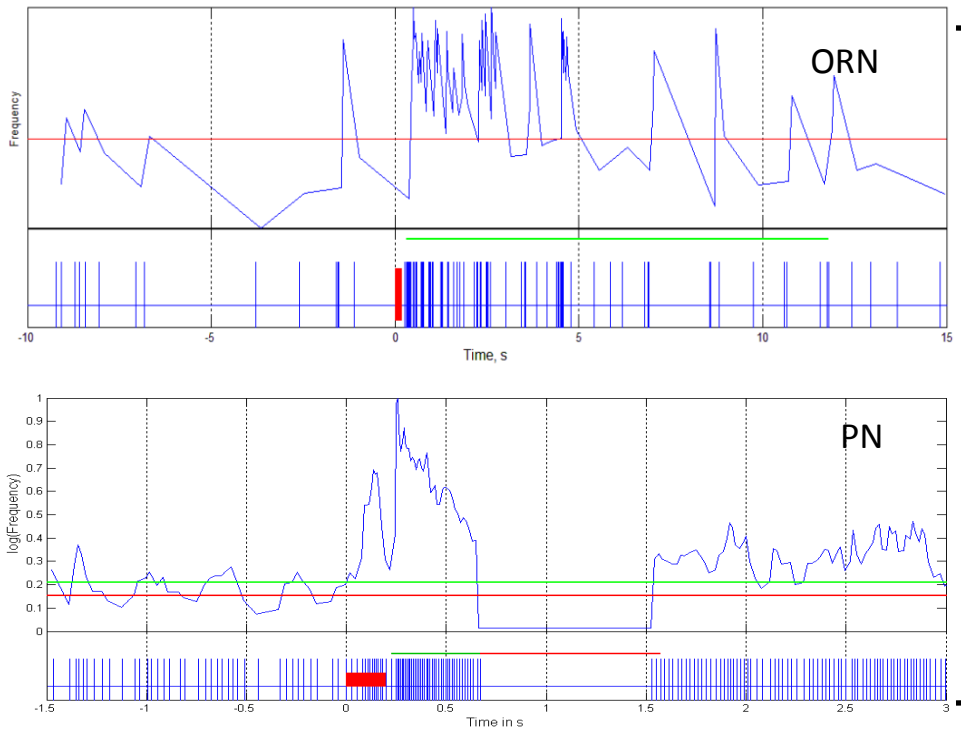
- Statistical analysis of single PNs

- Comparison with input parameters (ORN population)

-Connect previous computational model to a simple PN model.

-Eventually add more ingredients

Method used for analysis



F_S=median of spontaneous frequency

Excitation : $2.F_S$

1. Response detection algorithm

Excitation: F_S

Inhibition : F_S /2

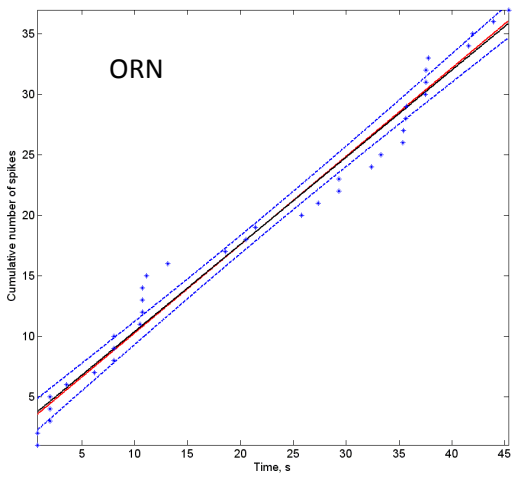
2. Fitting Dose-response curves:
-Frequency
-Latency
-Response duration
-Number of AP

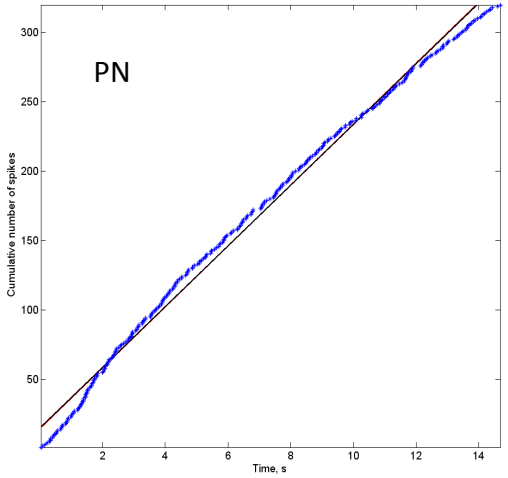
3. Fitting Parameter distributions

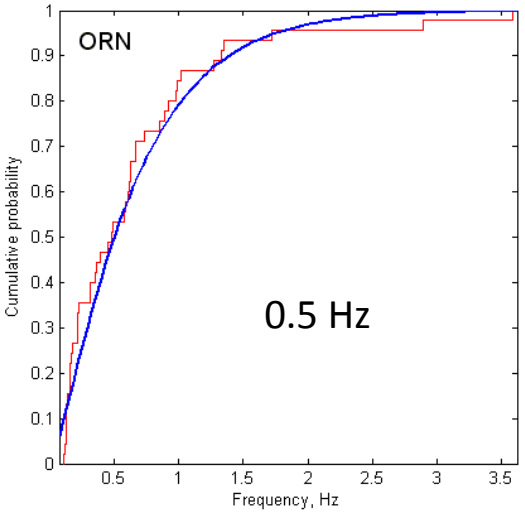
Spontaneous activity is very different

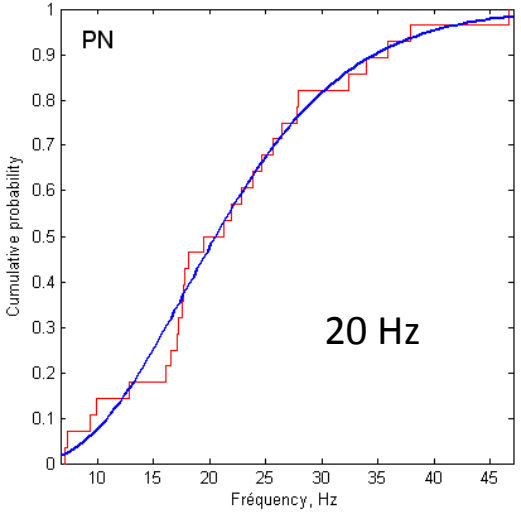
The slope of linear regression =mean frequency

Distribution of mean spontaneous frequency







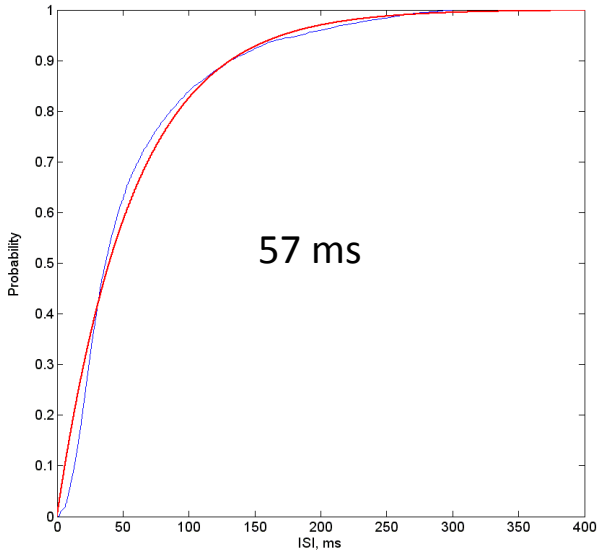


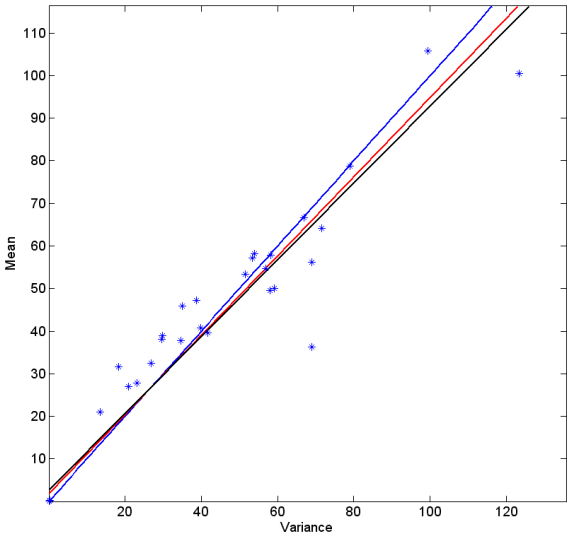
PN spontaneous activity process

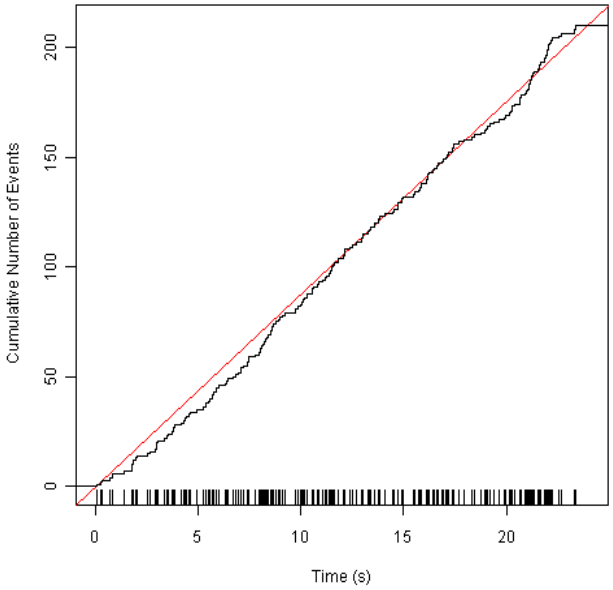
Exponential distribution

mean=variance

Close to an uniform Poisson process



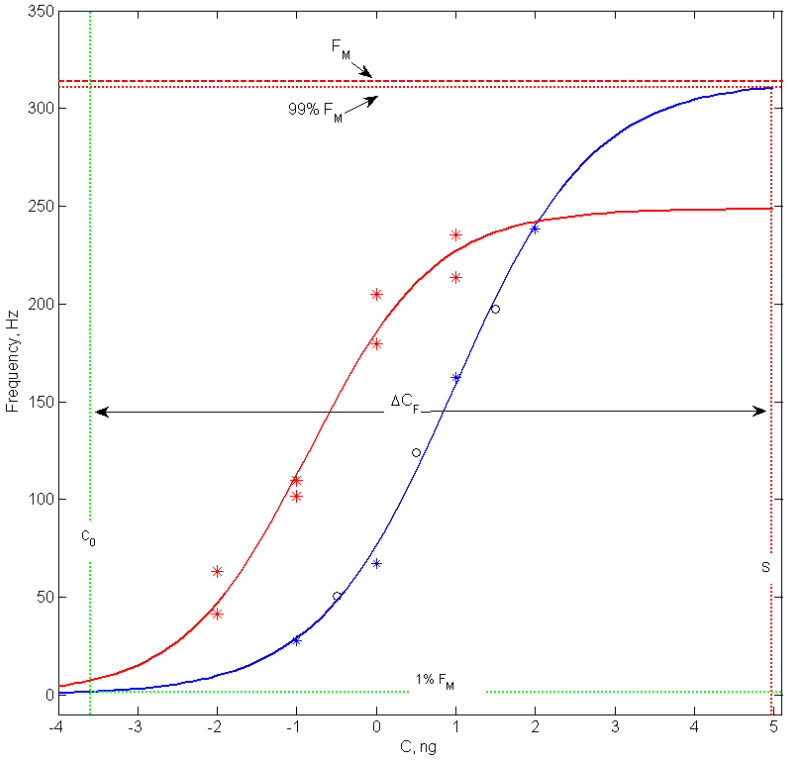




Spontaneous activity is close to be Poissonian in PNs

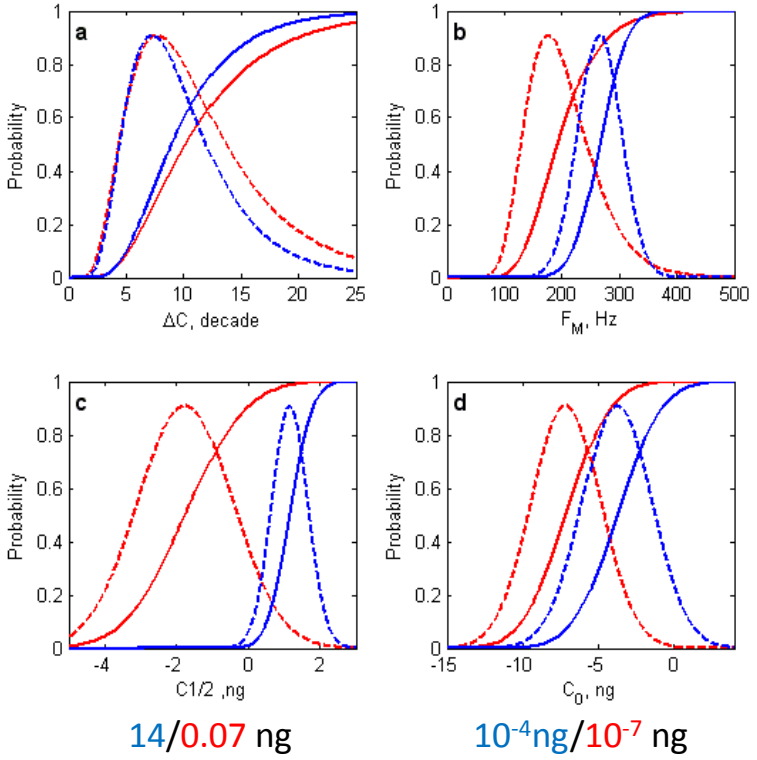
What about ORNs?

PNs are more sensitive than ORNs



8.9/10.2 decades

265/192 Hz



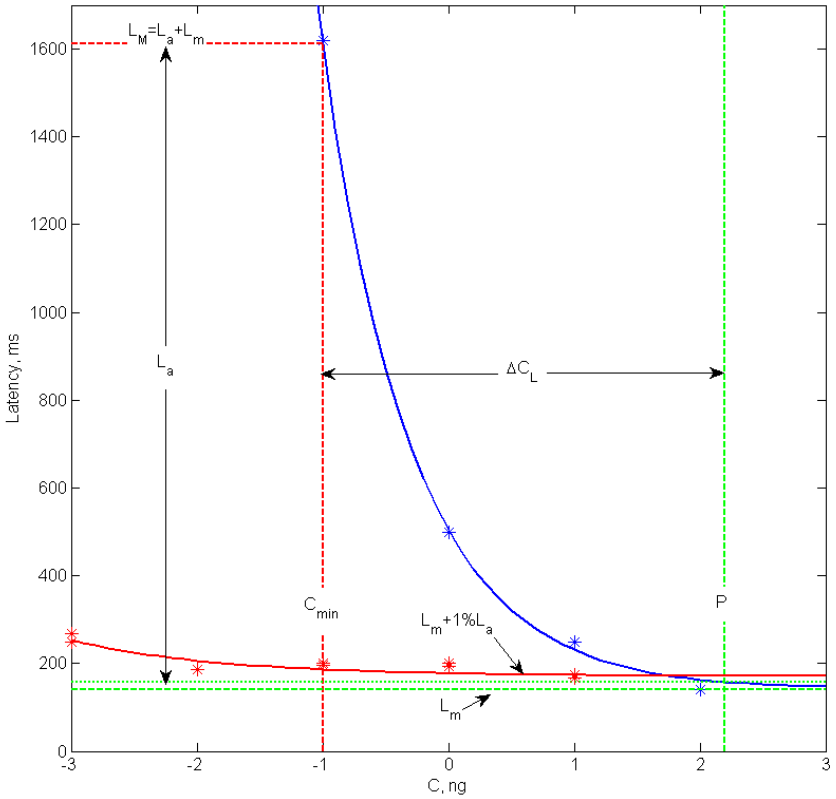
14/0.07 ng

10^{-4}ng/10^{-7} ng

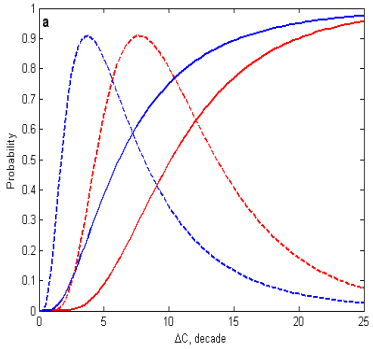
-PNs tuned to a larger dose range than ORN (ΔC larger)

-PNs are more sensitive (x 1000)

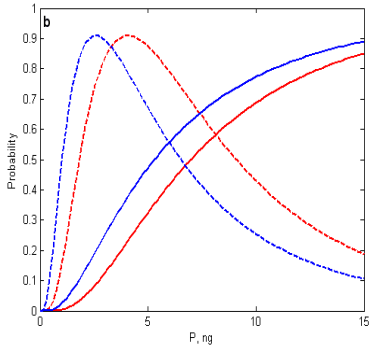
Latency ↗ exponentially when dose ↘



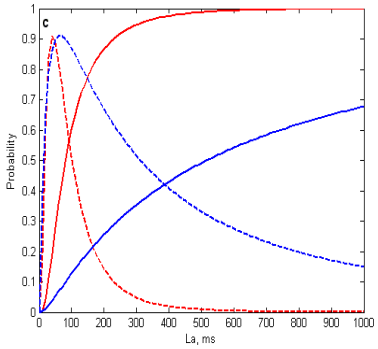
6.2/10.2 decades



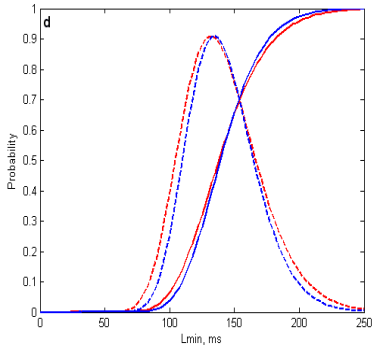
100/9000 µg



518/80 ms



139/150 ms

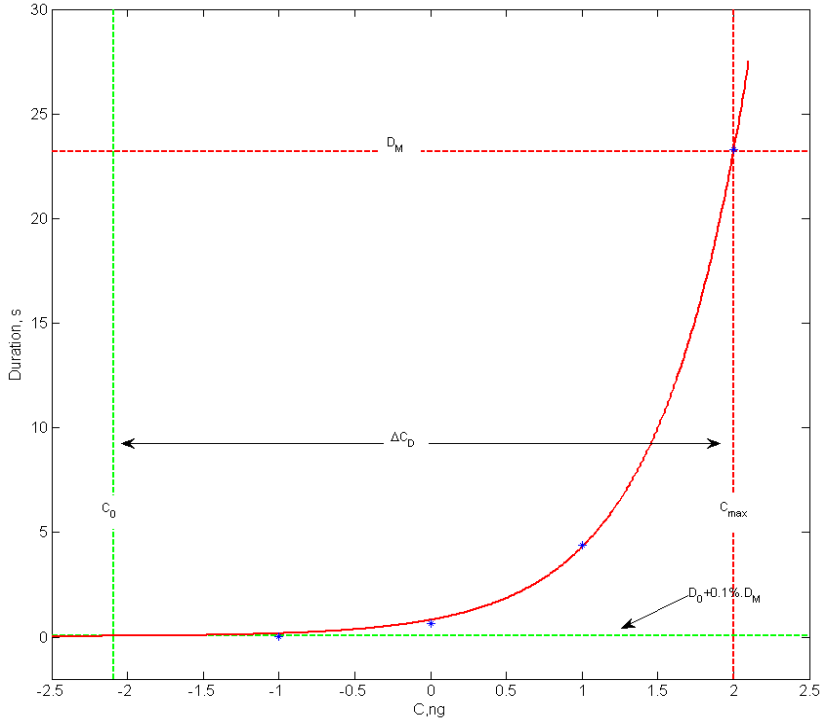


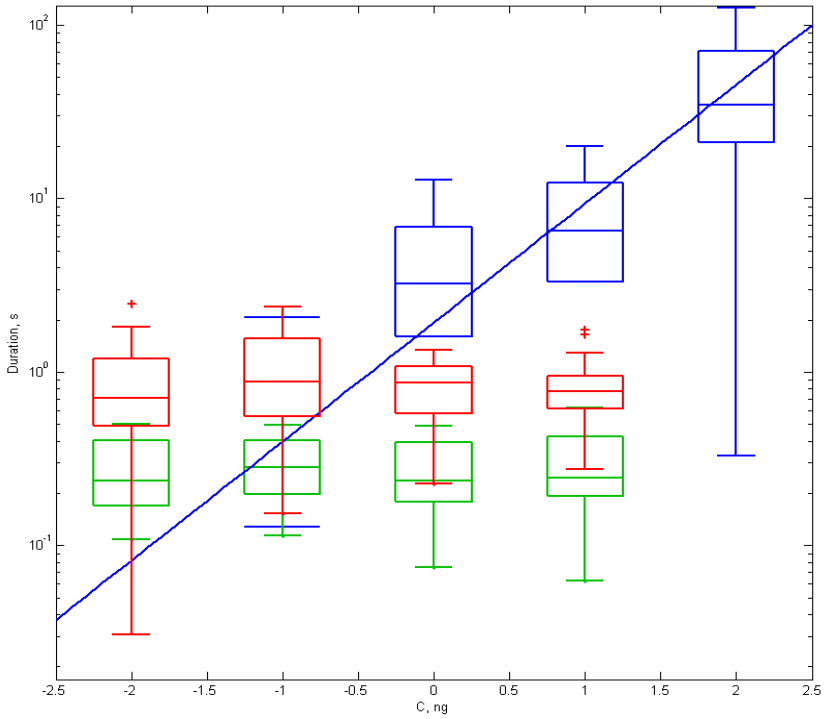
-Same minimum latency (Lm)

-ORNs are more sensitive to dose (P higher)

-ORNs latency is more variable for low doses

PN first excitation phase is dose-independent



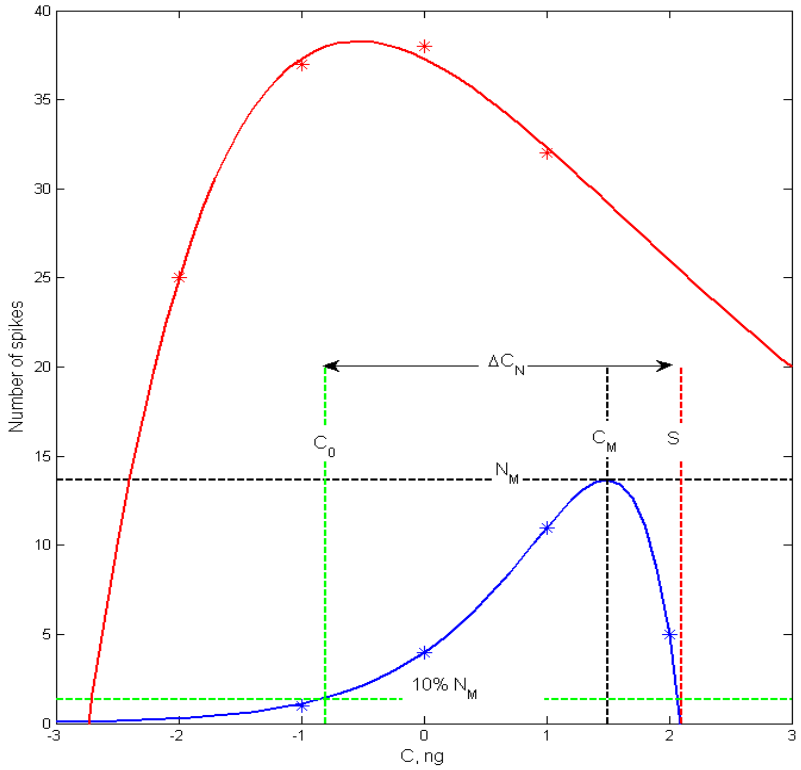


-Excitation phase of PNs is insensitive to dose (350ms)

-Inhibition phase is insensitive to dose (770ms)

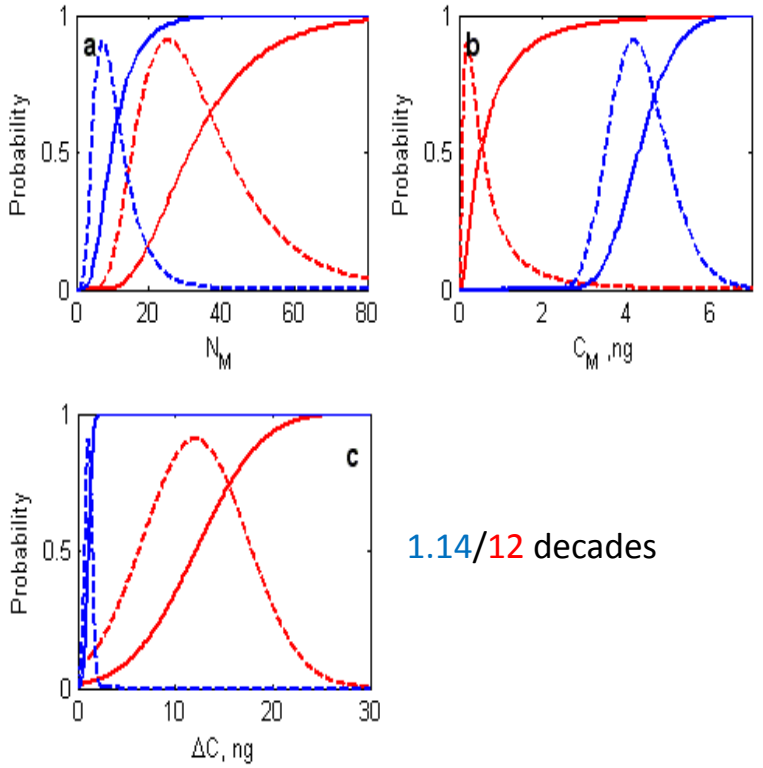
-ORNs response duration increases exponentially with the dose.

The number of AP ↗ at low doses & ↘ for high doses



9/28 spikes

20/10^{-3} µg



1.14/12 decades

- The number of AP in PNs for low doses increases dramatically

-The number of AP in PNs is higher than in ORNs

The comparison ORN/PN raises questions

- Why are single PN much more sensitive than a single ORN?
- Why do PNs respond faster than 90% of ORNs?
- Why does PNs response duration seems insensitive to dose while it increase exponentially in ORNs?
- Why are PNs and ORNs spontaneous activities so different?

A simple model to answer questions

- N ORNs converge toward 1 PN
- All ORNs have the same weight
- All ORNs are stimulated
- Each AP in an ORN gives an AP in a PN

The model is tested on spontaneous activity

F_{SP} =20 Hz / F_{SR}=0.5Hz

N ORN at F_{SR} → F_{SP}= N x F_{SR} → N=40 ?

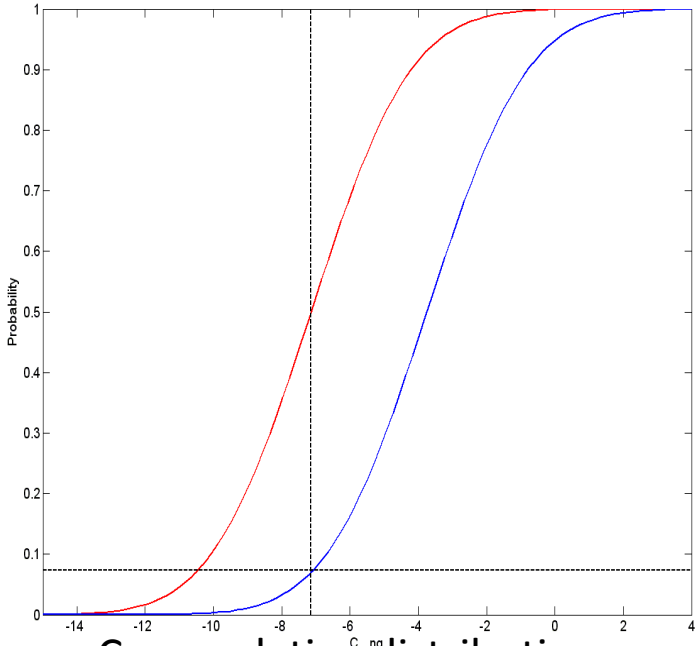
OR

Several AP in ORN = 1 AP in PN → Weak synapses?

→ High threshold ?

→ Inhibition ?

The sensitivity of PNs is due to strong convergence



C_0 cumulative distribution

7% of ORN trigger the response for a typical PN

- Spontaneous activity standard deviation:

$$\sqrt{N.F_{SR}.T}$$

- The signal noise ratio is expressed by:

$$S_E = F_{OR} \cdot p\sqrt{\frac{T \cdot N}{F_{SR}}}$$

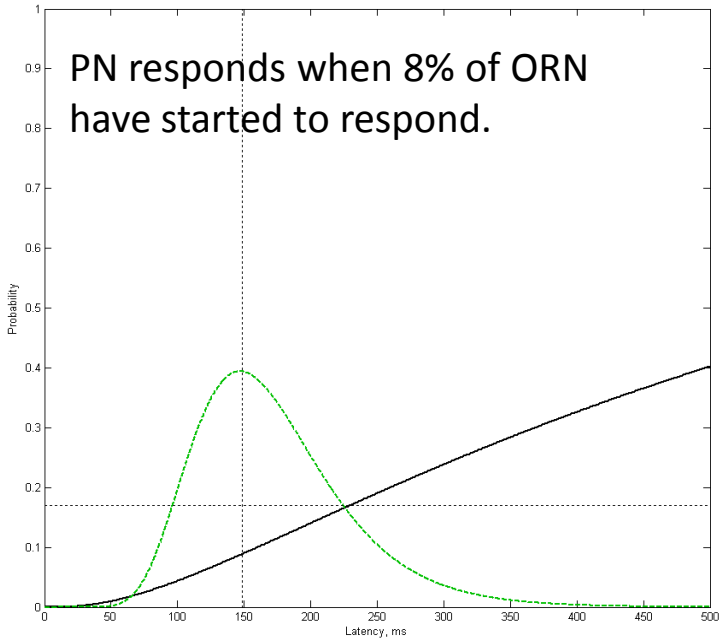
- A.N: p=0.07 , F_{SR}=0.5 Hz, F_{OR} =F_{SR} + 1 Hz, T=1s.

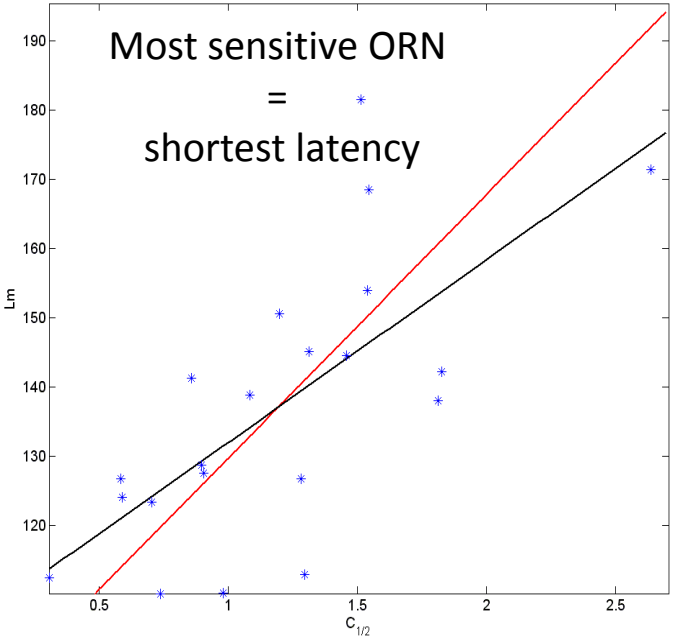
$$S_E \cong \sqrt{N}/6$$

- We assume the PN works close to the theoretical limit: $S_E \geq 3$ (Kaissling 2009)

- Then in first estimation and in average: **N≈400**

Strong convergence is confirmed





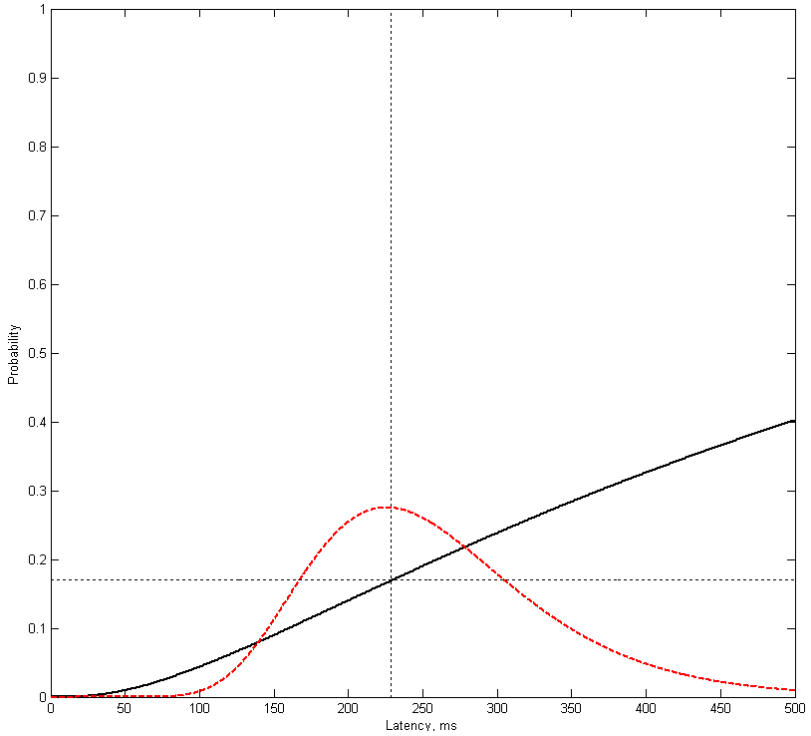
Consistancy with previous result=
8% of ORN population trigger PN response

↓

High convergence ratio, N

PN reaches max frequency faster than ORN population

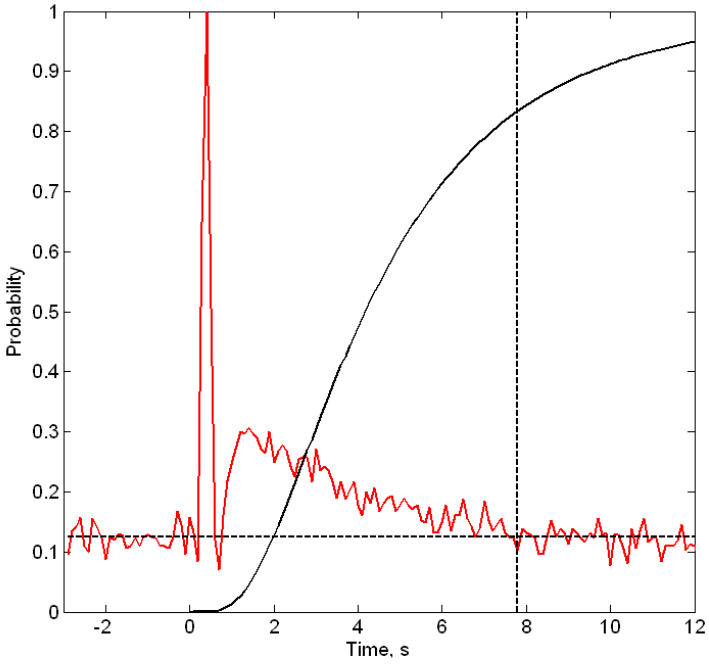
PN reaches maximum frequency when 17% of ORN have started to respond.



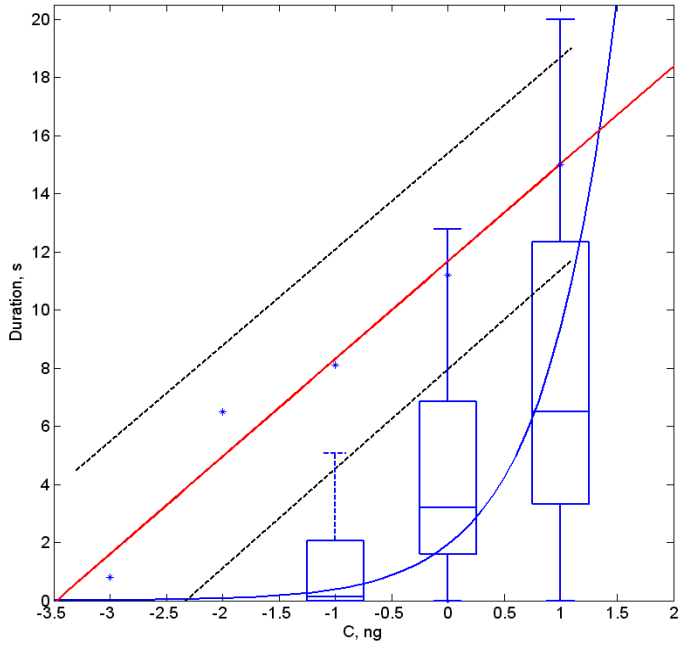
Activity in PN is maximal while it is still increasing in ORN population.

- Inhibition?
- Higher response threshold?

PN response continues after inhibition



PN stops to respond when
83% of ORNs have responded



ORNs response ≈ 400 ms

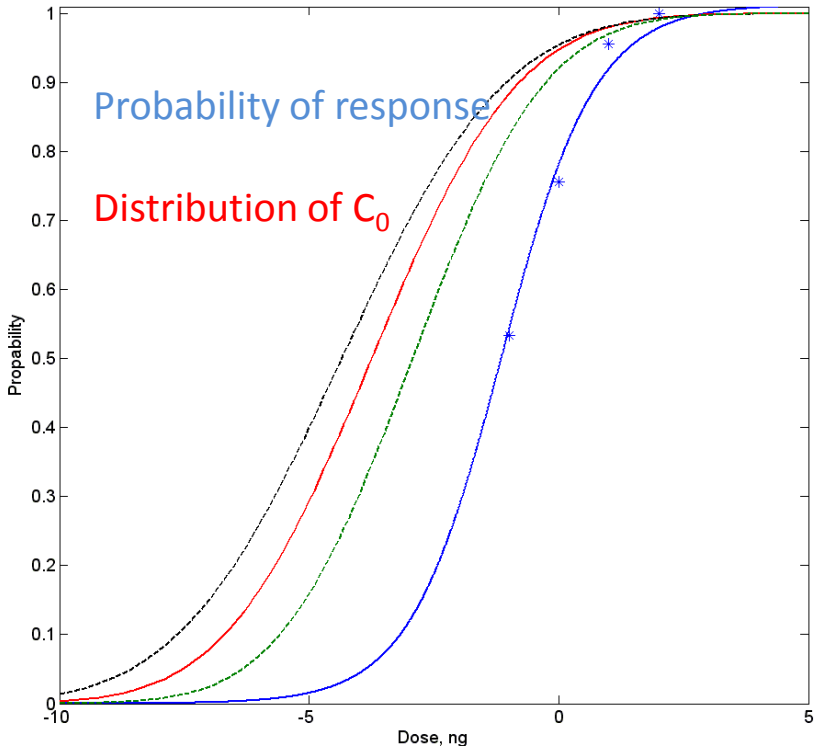
+

Variability in ORN population (L, D)

↓

PNs response ≈ 10 s

All the ORNs are not stimulated



Probability that an ORN can respond

≤

probability to respond

ORNs are probably not all stimulated

The model is partially validated

- N ORN converge toward 1 PN ✓ N≥400
- All ORN have the same weight ✓
- All ORN are stimulated ✗
- Each AP in ORN gives an AP in PN ✗

- Inhibition ?

- Response Threshold ?

Perspectives: Build a computational model

- Build a computational model of ORN population using directly parameter distributions

- Probability of response
  - modelling pheromone flux
  - build a simple geometrical model of antennae

- Build a simple computational model of PN (I&F)