German cockroach bait aversion

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Blattella germanica – German cockroach

- Exclusively synanthropic
  - No evidence of populations apart from human-maintained structures
- Omnivores
- Coprophages

- Semisocial
  - aggregations

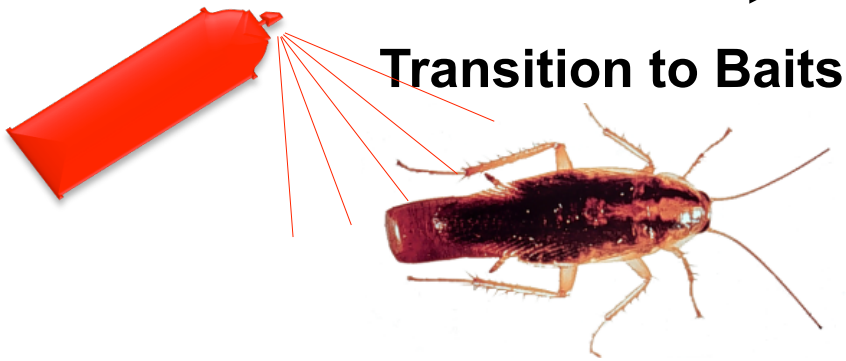
Roaches in sliding door

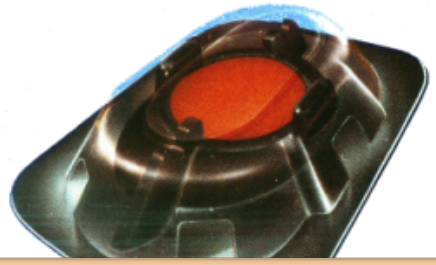
Blattella germanica - Importance

- Potent source of allergens causing asthma
- Mechanical vector of pathogens
- Nuisance, necessitating control with insecticides
  - Health and environmental impacts

Since mid-1980s

Transition to Baits





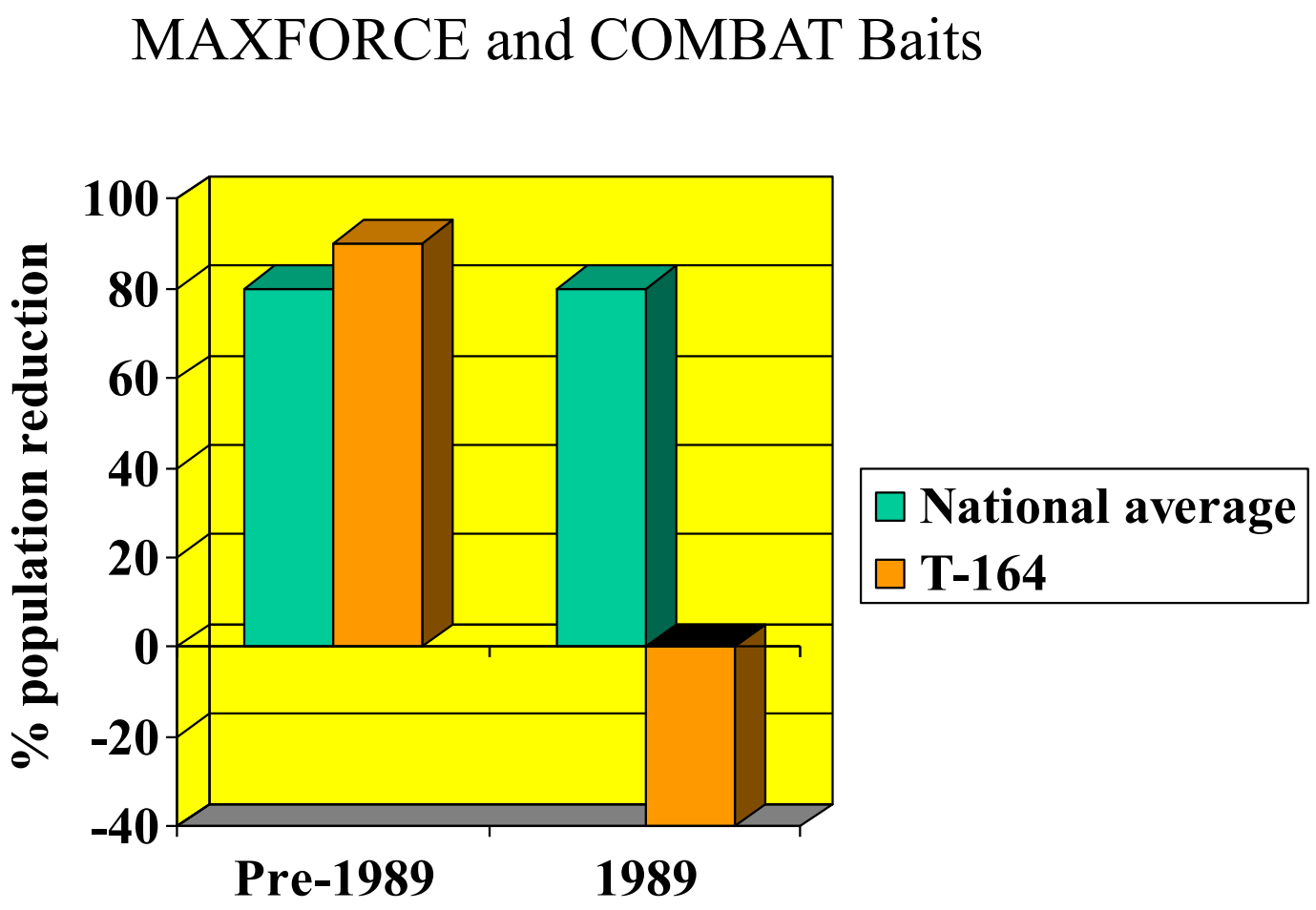
- Extremely high selection pressure for the evolution of insecticide resistance
- Some evidence of physiological/metabolic resistance to the AI

Product performance assessment

Bait Performance Decline Observed in Scattered Locations Across the Globe

- e.g. Florida, California, Puerto Rico, South Korea

Product performance decline



What went wrong?

- Determined that baits were effective against lab strain – i.e. no manufacturing errors
- T-164 *Blattella* were not resistant to hydramethylnon

What went wrong?

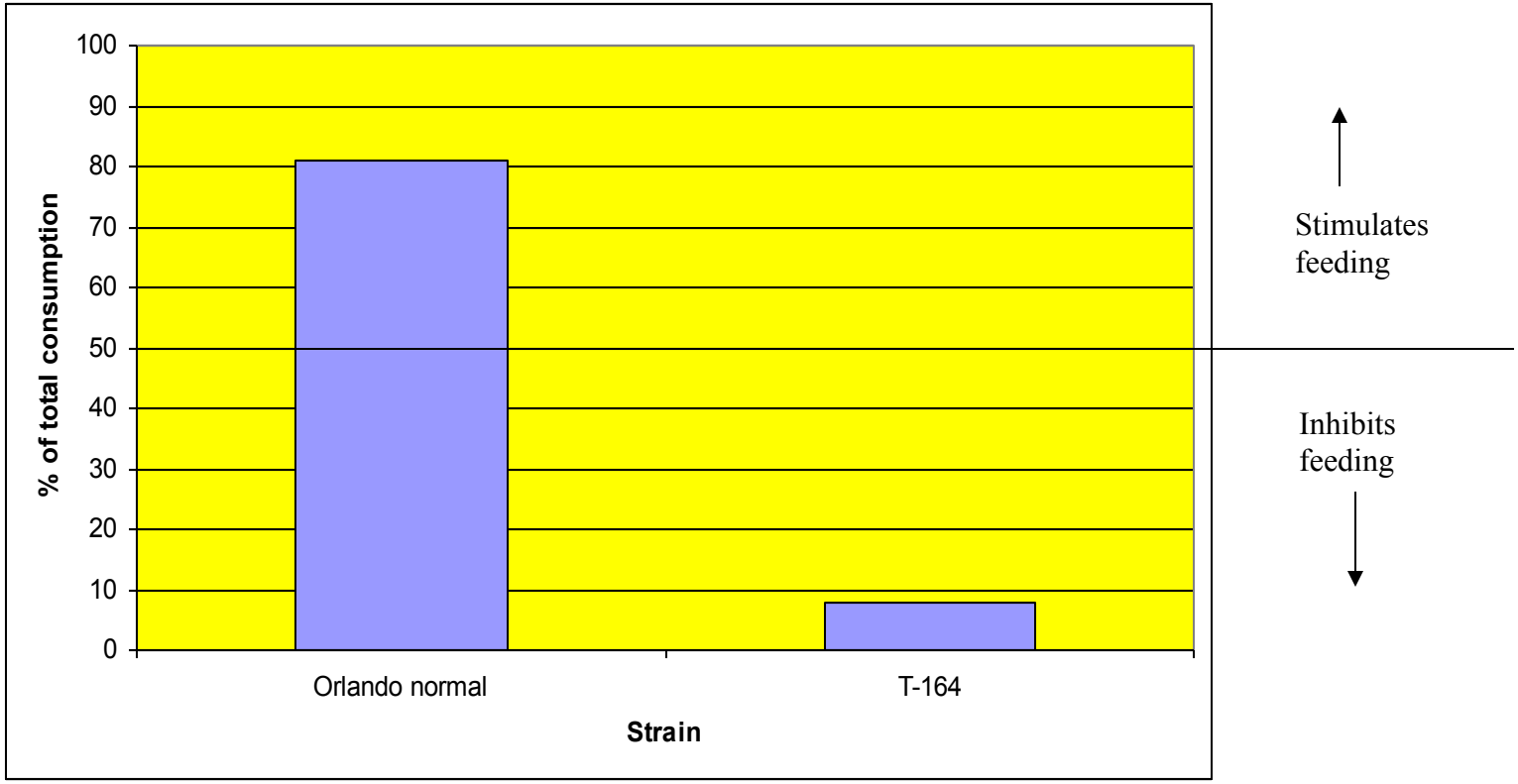
- Determined that baits were not consumed by T-164 and some other strains
- Subsequently deleted bait components one by one and evaluated against T-164

Bait component deletion study findings

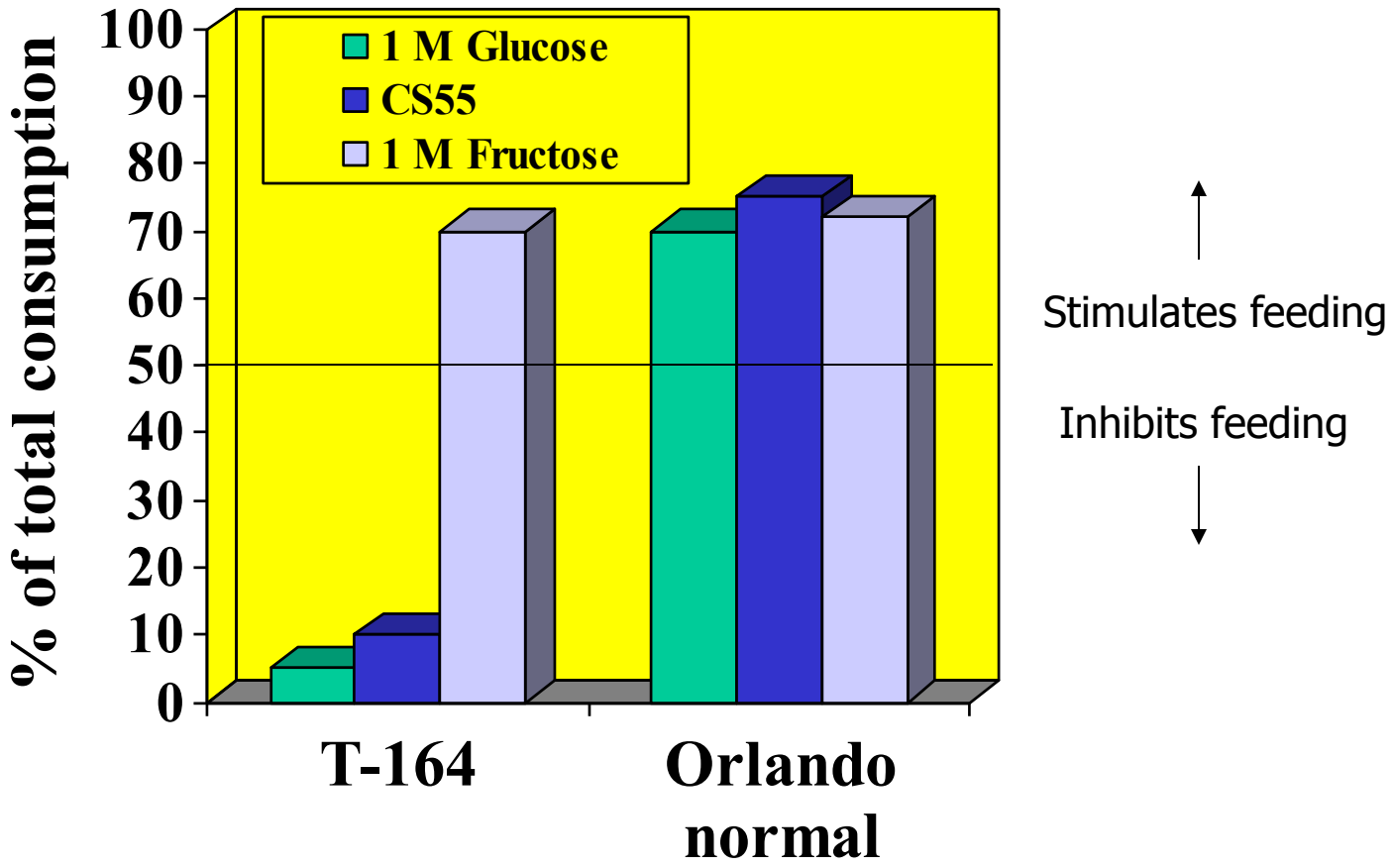
- No rejection of hydramethylnon
- No rejection of bait binders
- No rejection of preservatives
- No rejection of oatmeal

- What's left?

Effect of corn syrup on strain consumption



Effect of sugar on consumption by cockroach strain



Glucose aversion and food preference

Fructose/agar

Glucose/agar

Wild-type

Glucose-averse

Genetics of glucose aversion

- Incompletely-dominant
- Autosomal
- Likely single major gene
- Chromosome 9

Glucose aversion:
A case of behavioral resistance

J. Insect Physiol. Vol. 39, No. 11, pp. 925–933, 1993
Printed in Great Britain.

Glucose Aversion in the German Cockroach, *Blattella germanica*

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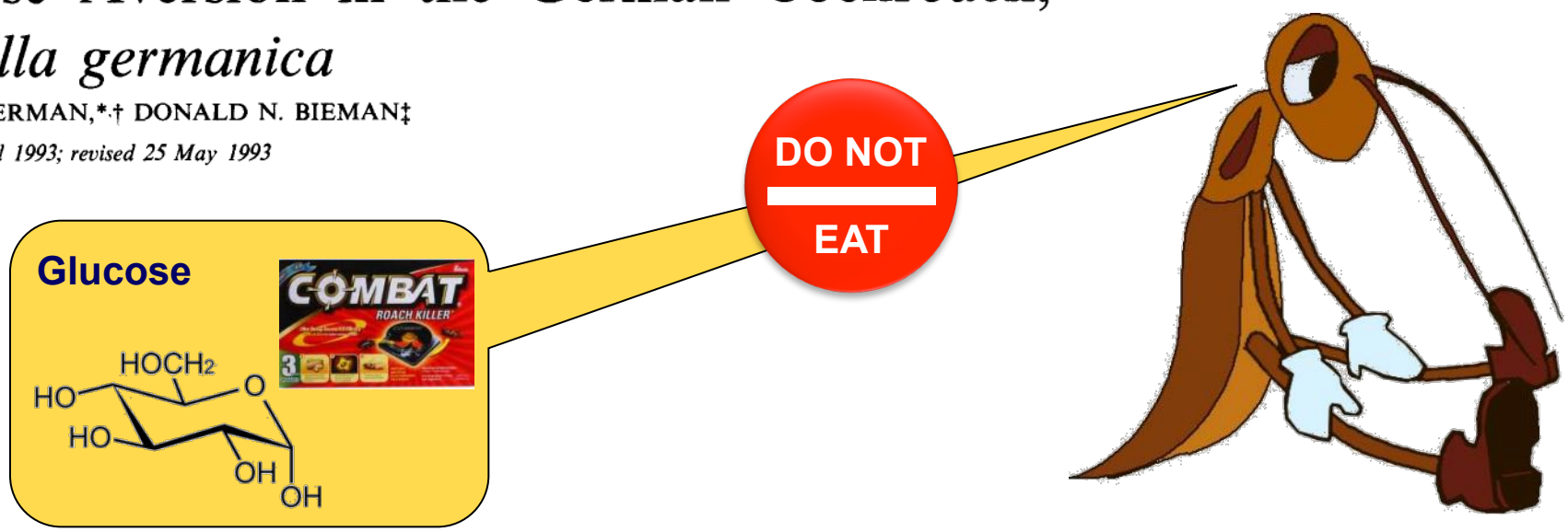


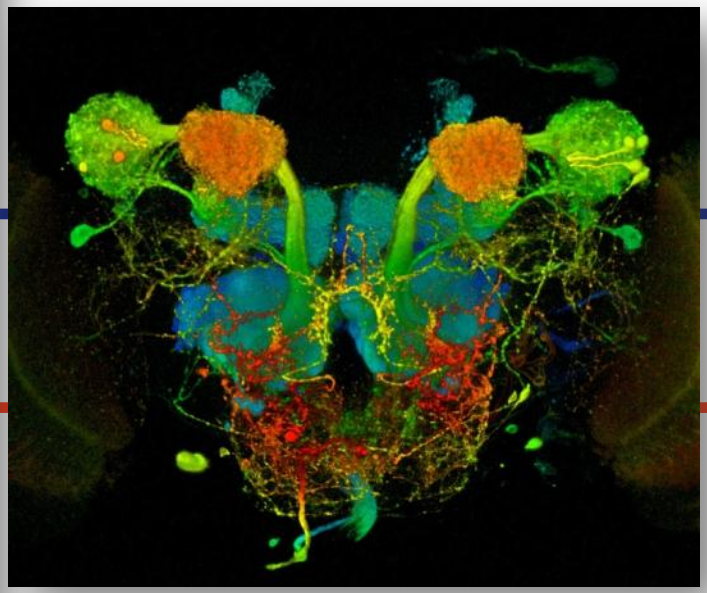
- Behavioral aversion to a bait ingredient, but **not** to the AI
- Glucose is **not** toxic
- Genetically-based
- Highly adaptive under toxic bait pressure
- Multiple populations

How do cockroaches mis-process glucose as a deterrent?

Glucose-aversion: Peripheral *vs.* Central?

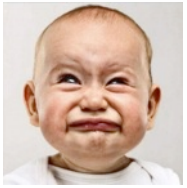
Peripheral ?

CNS ?



Acceptance

Rejection



Tastants → GRs → GRNs

Brain processing

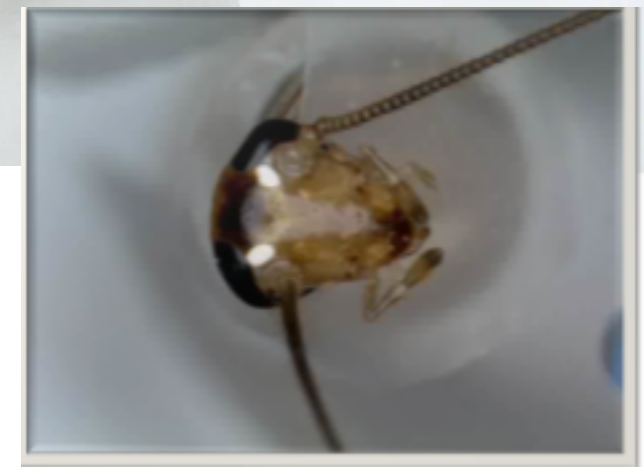
Behavior expressed

Which sensory appendages are involved?

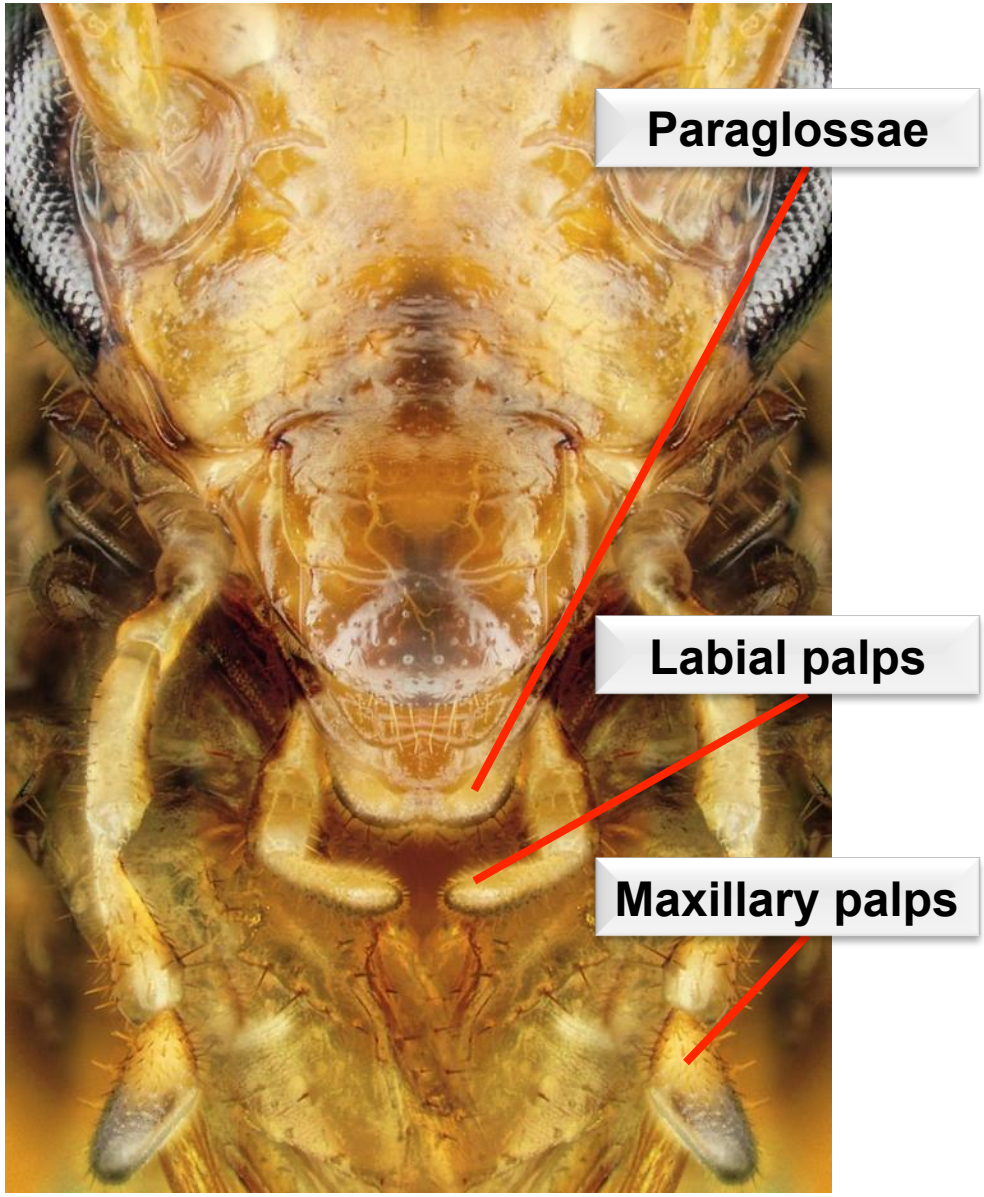
Ablation assays

Wild-type

Glucose-averse



Paraglossae most important in glucose aversion

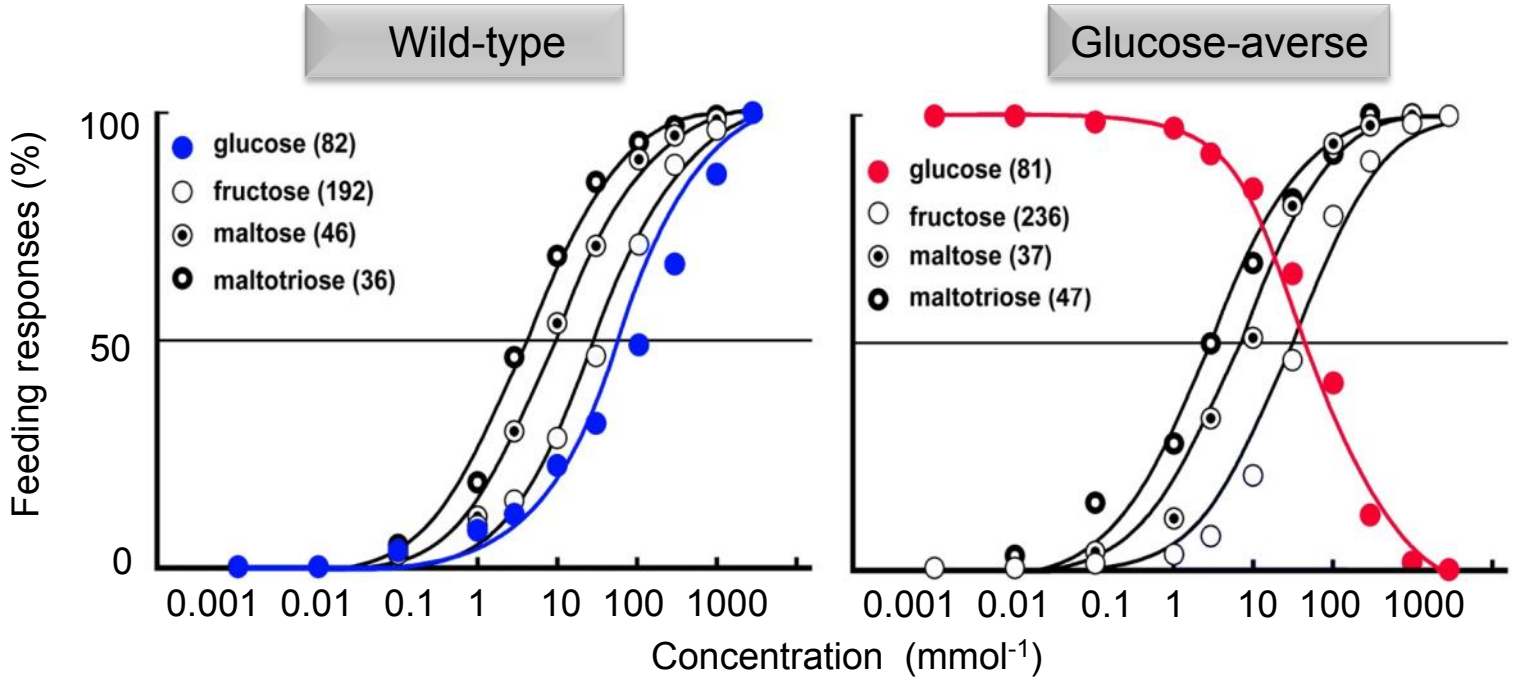


Ablation assays

Paraglossae represent a minimal sensory system for discriminating gustatory stimuli

Wada-Katsumata *et al*. 2011. *Chemical Senses*

Dose-response of the paraglossae to tastants



Wild-type

Glucose-averse

% cockroaches responding

100

50

0

glucose (82)
fructose (192)
maltose (46)
maltotriose (36)

glucose (81)
fructose (236)
maltose (37)
maltotriose (47)

Phagostimulants

Glucose
Fructose
Maltose
Maltotriose

caffeine (131)
quinine (121)
NaCl (34)

caffeine (139)
quinine (148)
NaCl (60)

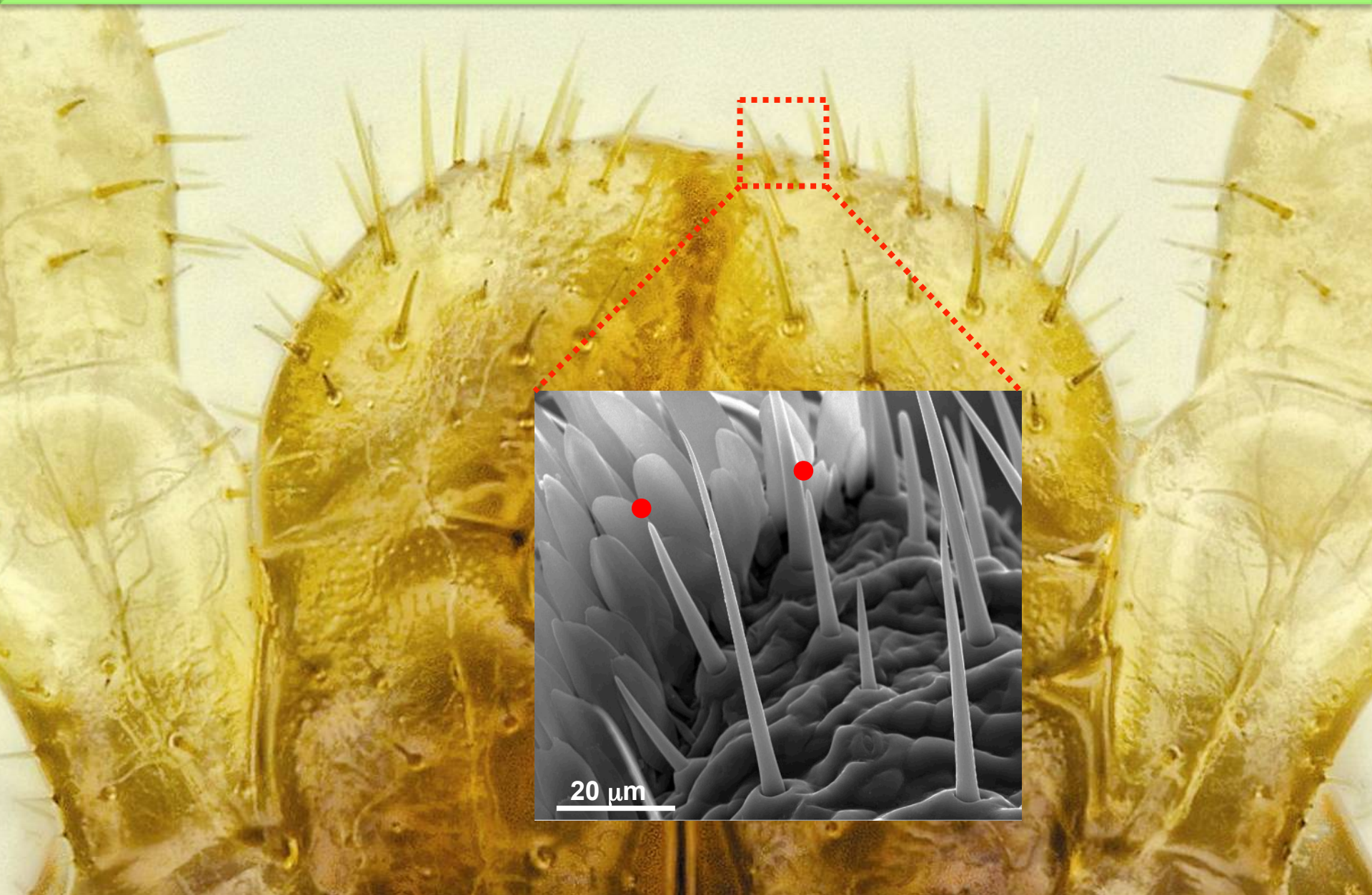
Deterrents

Caffeine
Quinine
NaCl

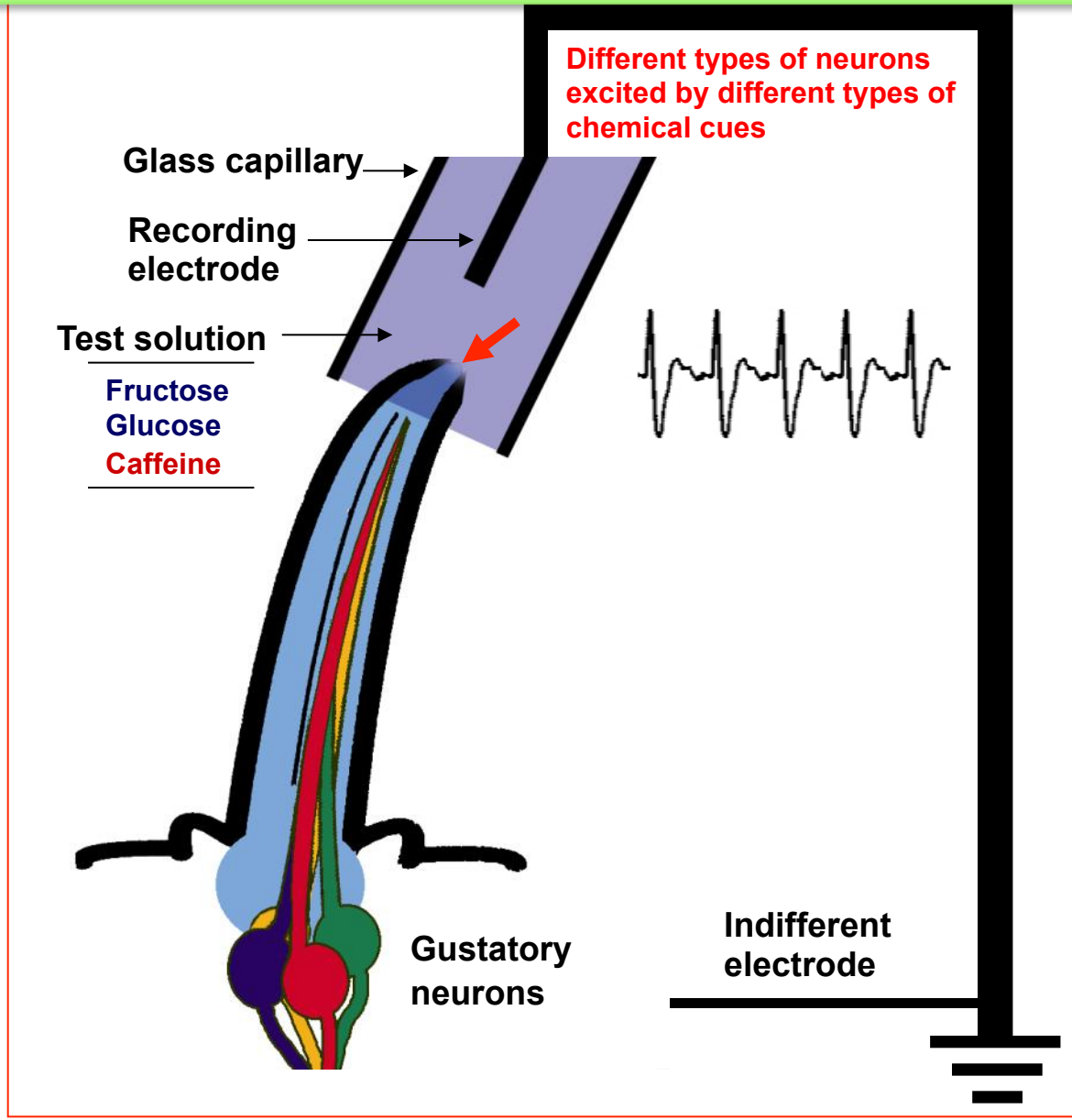
0.001 0.01 0.1 1 10 100 1000

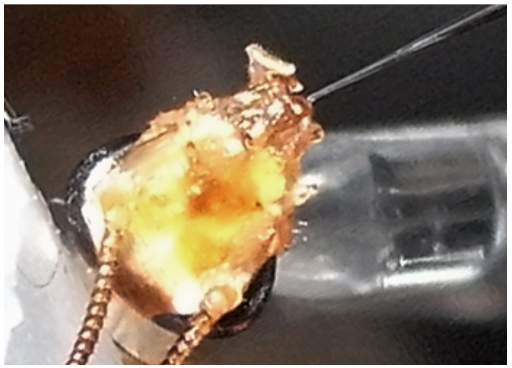
Concentration (mmol^{-1})

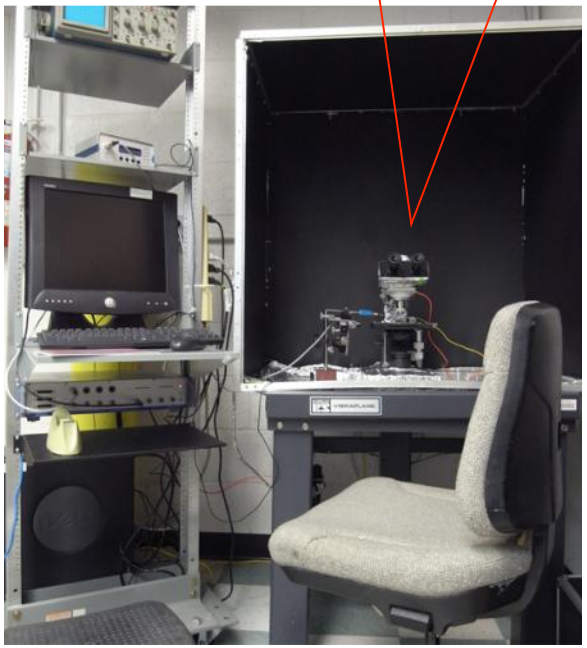
Do wild-type and glucose-averse strains differ in peripheral gustatory coding?



Sensory differences: Tip recording

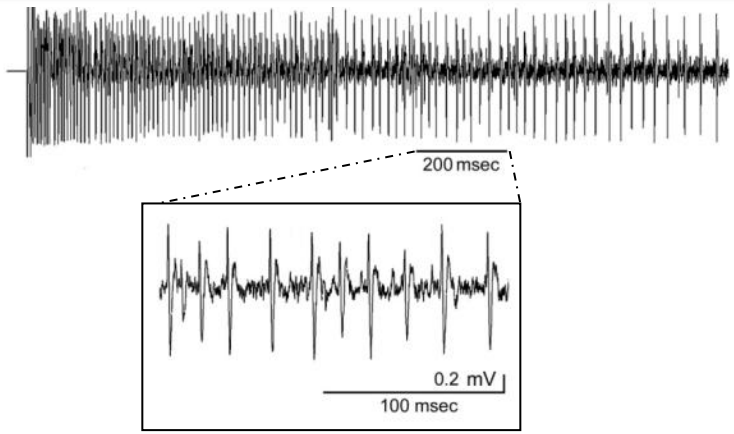




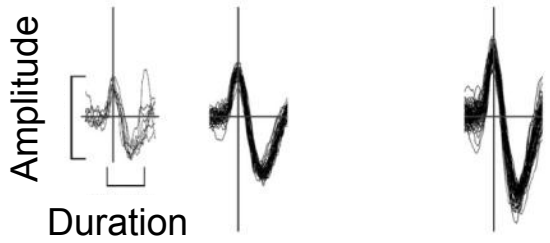


Analysis of neuronal responses

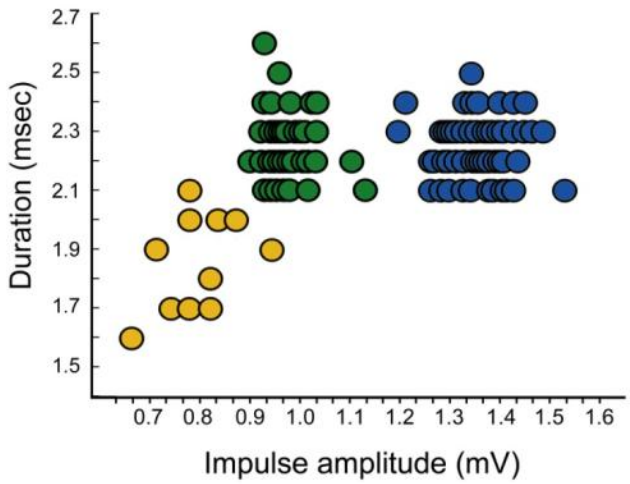
Fructose
(8 mmol^{-1})



Recording



Sorting of impulses
based on amplitude (mV) and duration (msec)



Cluster analysis

- **GRN1**
- **GRN3**
- **GRN4**

D-fructose stimulates 3 types of GRNs

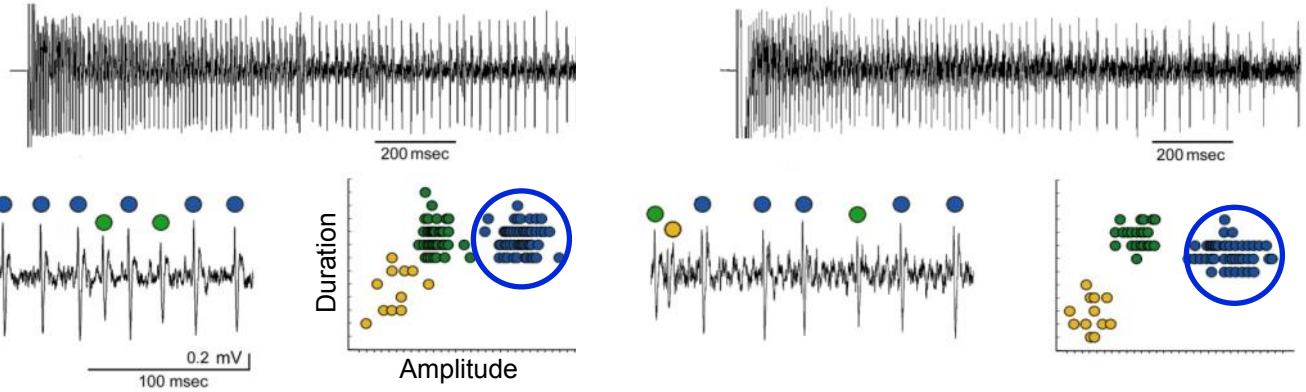
Wild-type

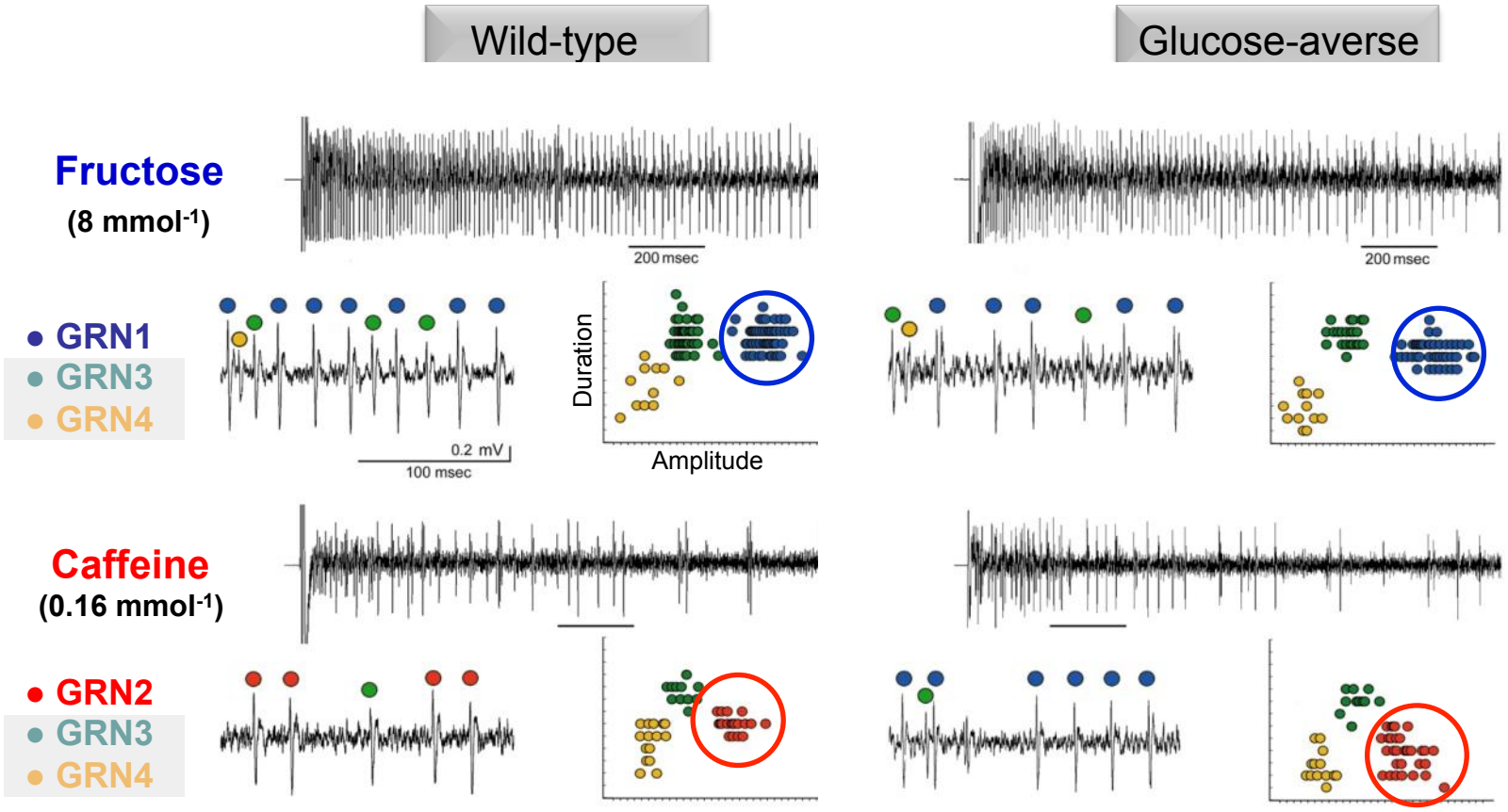
Glucose-averse

Fructose

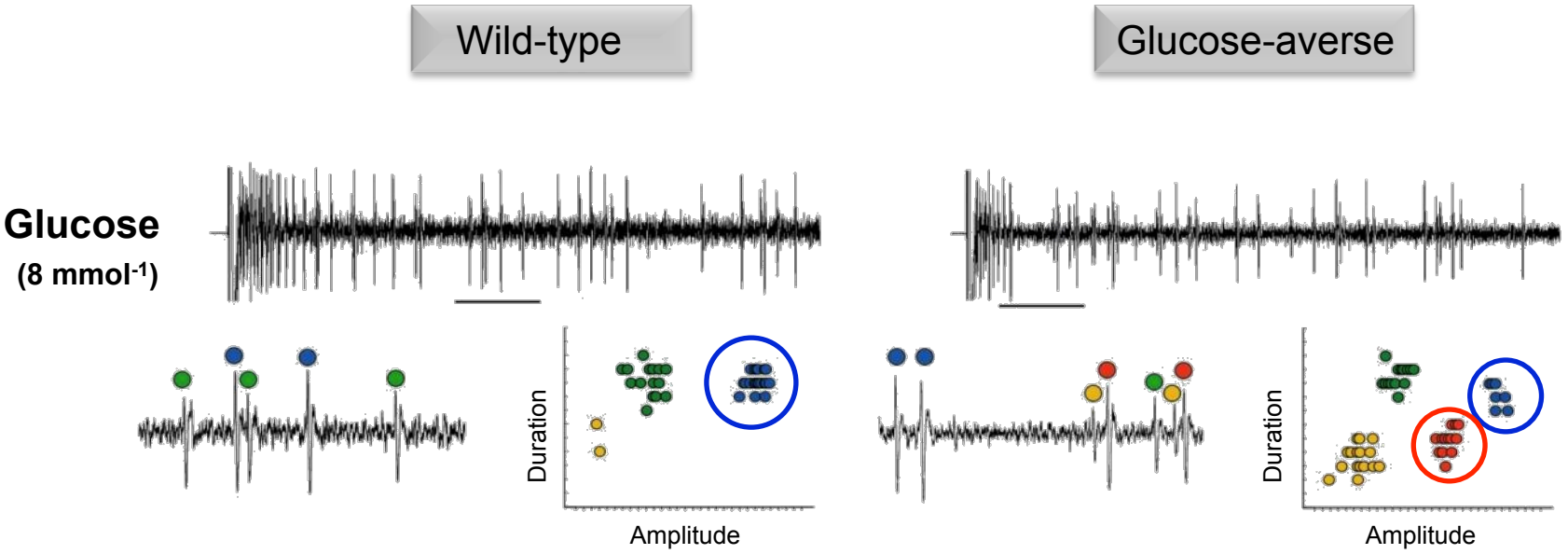
(8 mmol^{-1})

- **GRN1**
- **GRN3**
- **GRN4**





Fructose stimulated a sugar receptor neuron = GRN1
Caffeine stimulated a bitter receptor neuron = GRN2



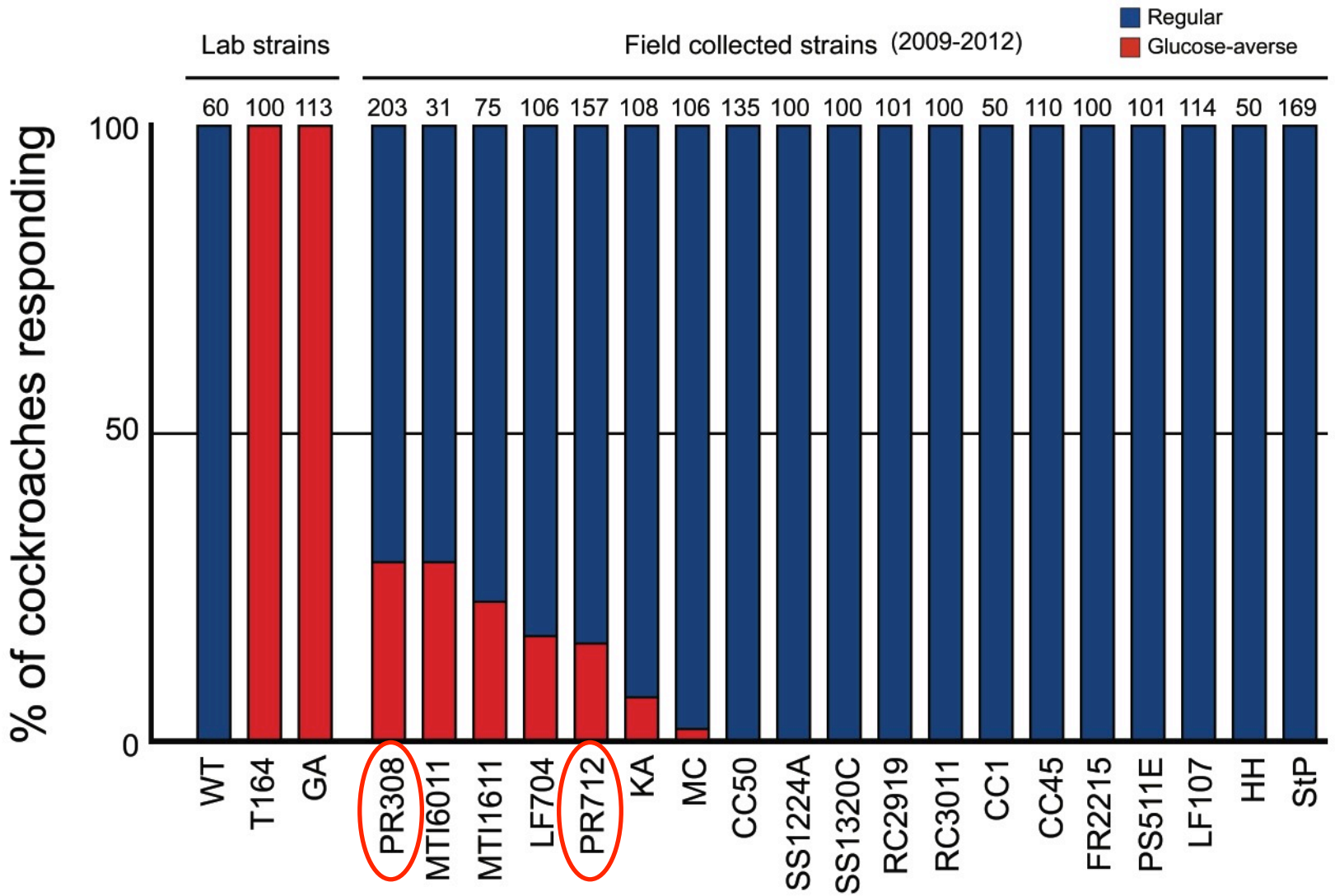
In glucose-averse cockroaches:

- Glucose stimulates both **sugar** and **bitter** receptor neurons

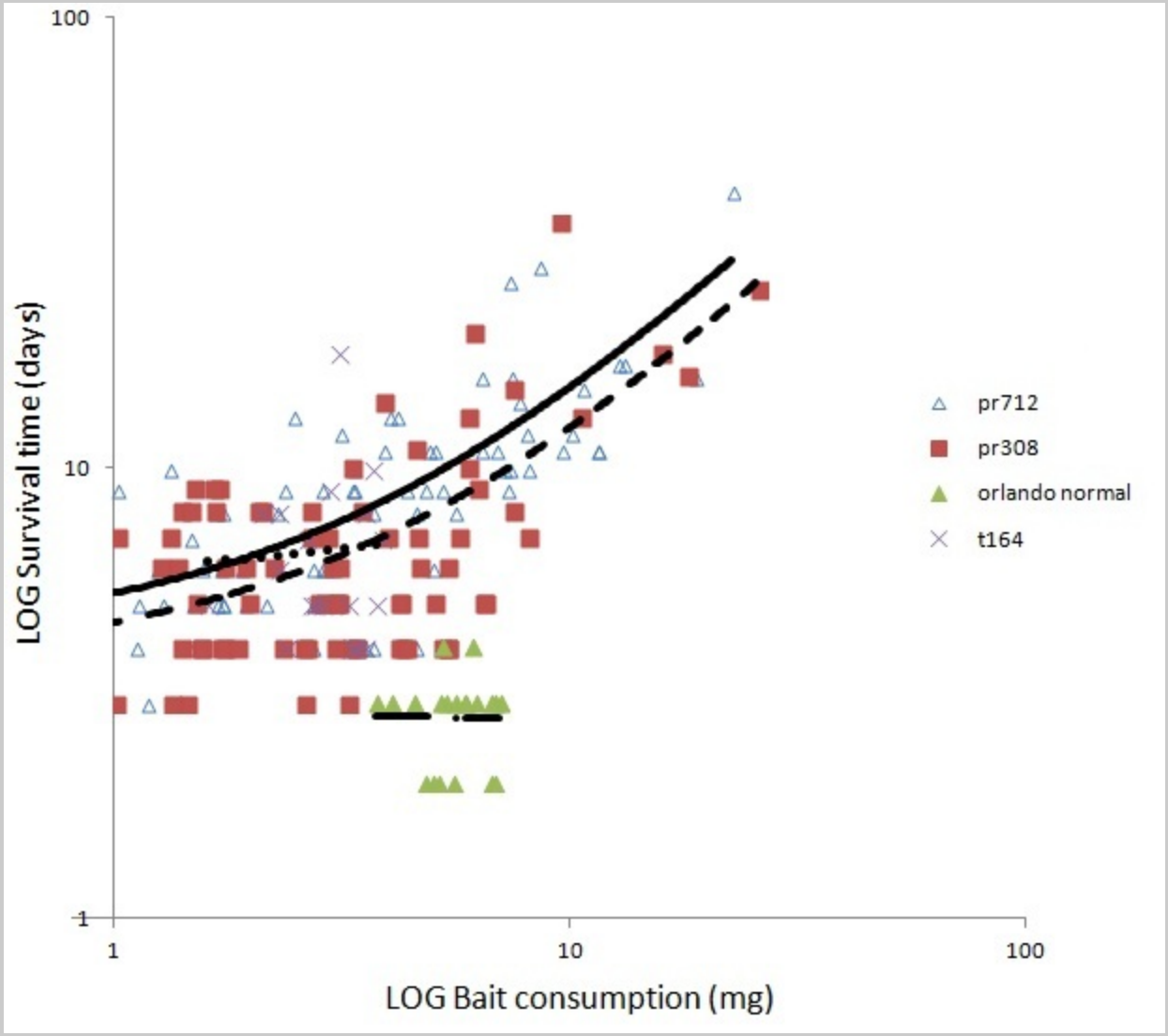
Changes in gustatory sensillum function underlie glucose aversion (CNS may also be involved)

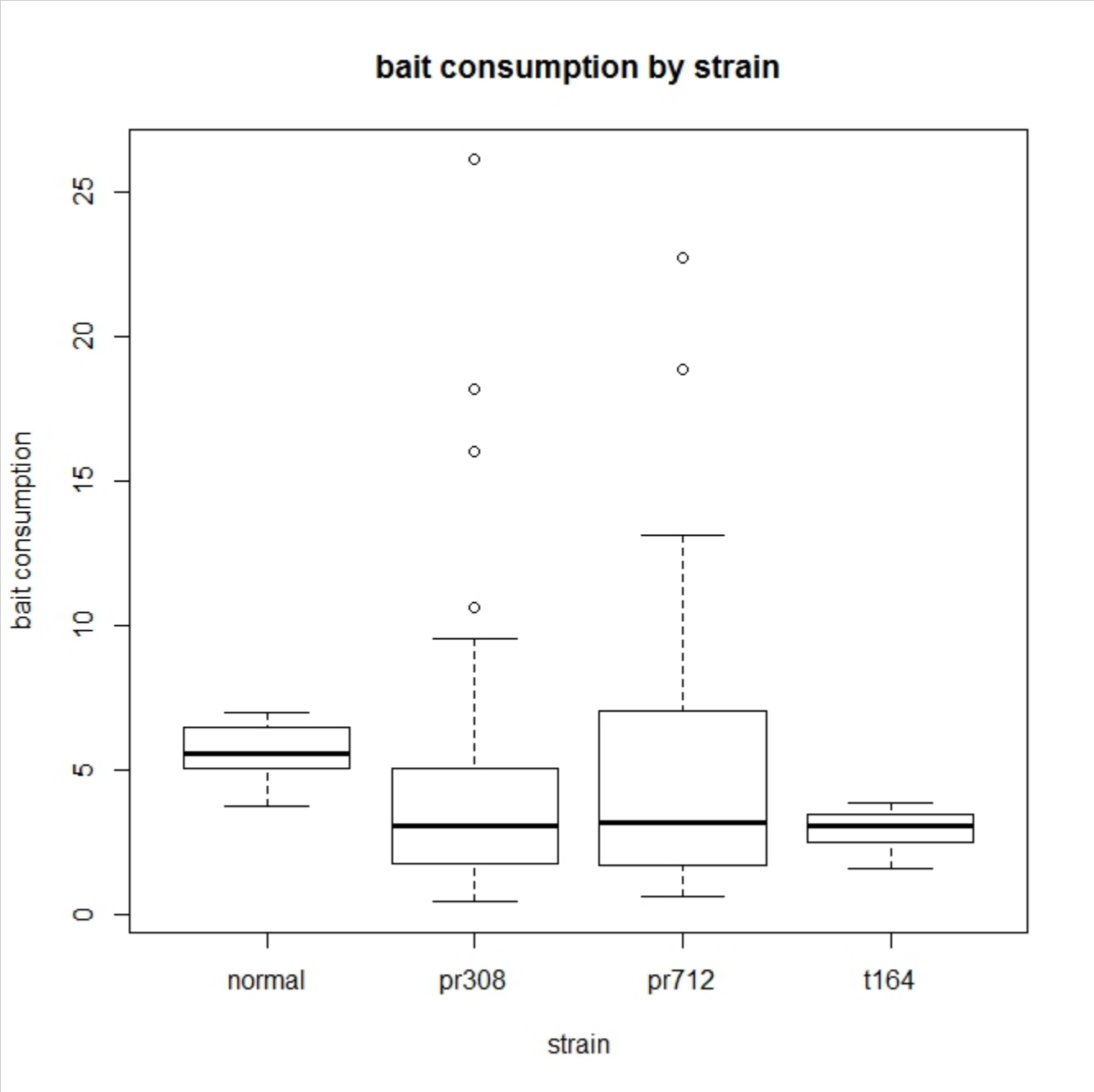
Wada-Katsumata *et al*. 2013. *Science*

Generalization: Other strains



Response to hydramethylnon – glucose bait




bait consumption by strain
bait consumption
0
5
10
15
20
25
normal
pr308
pr712
t164
strain

Resistance to Hydramethylnon

Resistance ratios – LD-50

- T-164 – 1.0
- PR 712 - 30.4
- PR 308 - 33.0

What's next?

- Assay other field-collected strains for resistance/aversion
- Resistance to other bait AIs?
- Aversions to other sugars (fructose)?
- Determine linkage between resistance and aversion (in population and/or individual)

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Southern IPM Center