

Mechanical and chemical cues regulating egg-laying in *Aedes aegypti* mosquitoes



Ben Matthews
Assistant Professor, Zoology
University of British Columbia, Vancouver

Vector Revolution
December 14, 2022

Neuroethology:
the study of the neural basis of naturalistic
behavior



Masakazu (Mark) Konishi

Gene

Neuron

Genome

Circuit

How does a genome encode the capacity for adaptive behaviors?

How does the nervous system implement these behaviors?

Behavior





Vi
Sa



What sensory cues do container breeding mosquitoes use to choose where to lay eggs?

Elevated relative humidity odorants

Visual cues



Physical (texture)

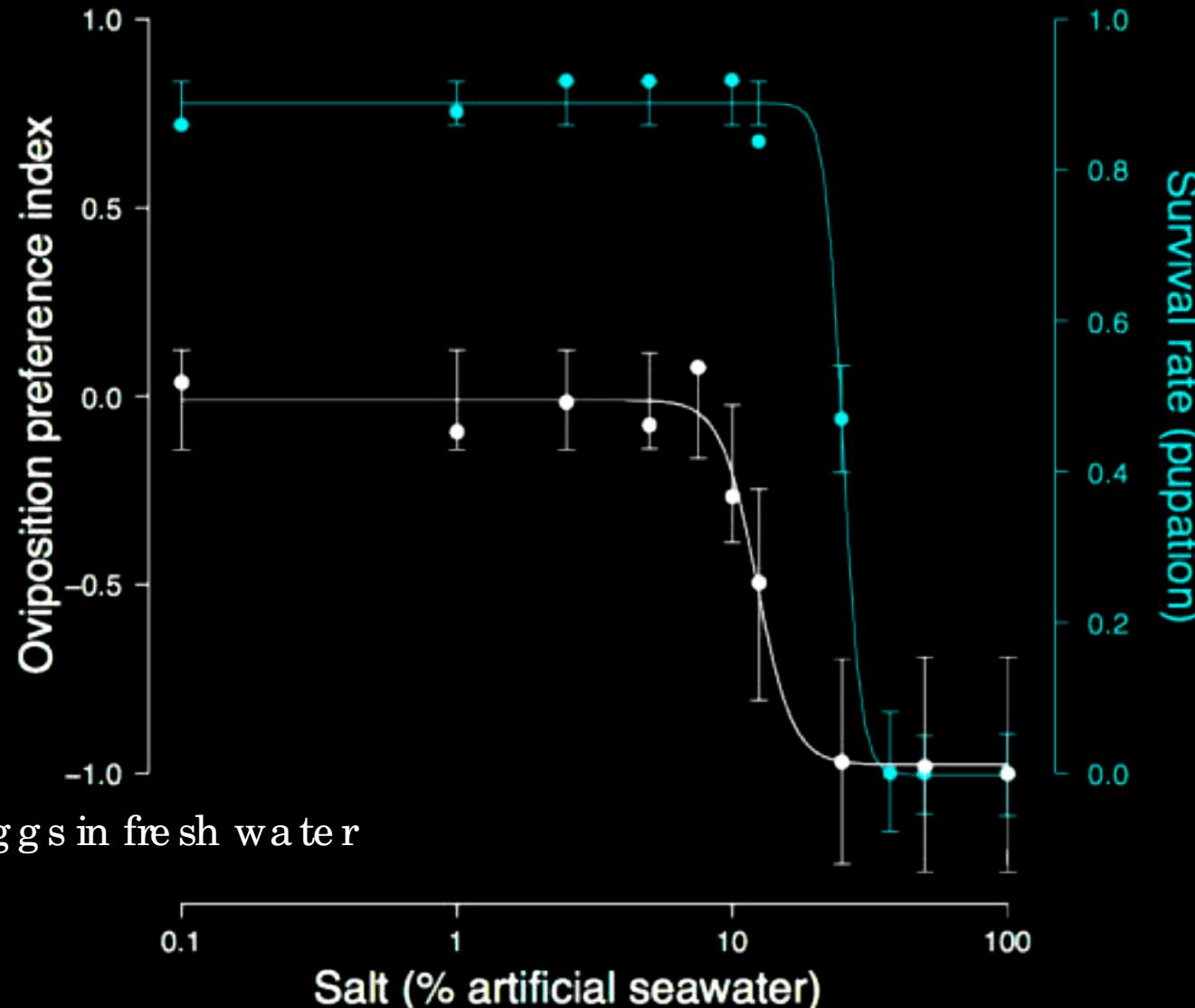
Taste cues

- Salinity
- Food
- Predators
- Toxins



Aedes aegypti show dose-dependent aversion to egg-laying in seawater

All eggs in salt water



All eggs in fresh water

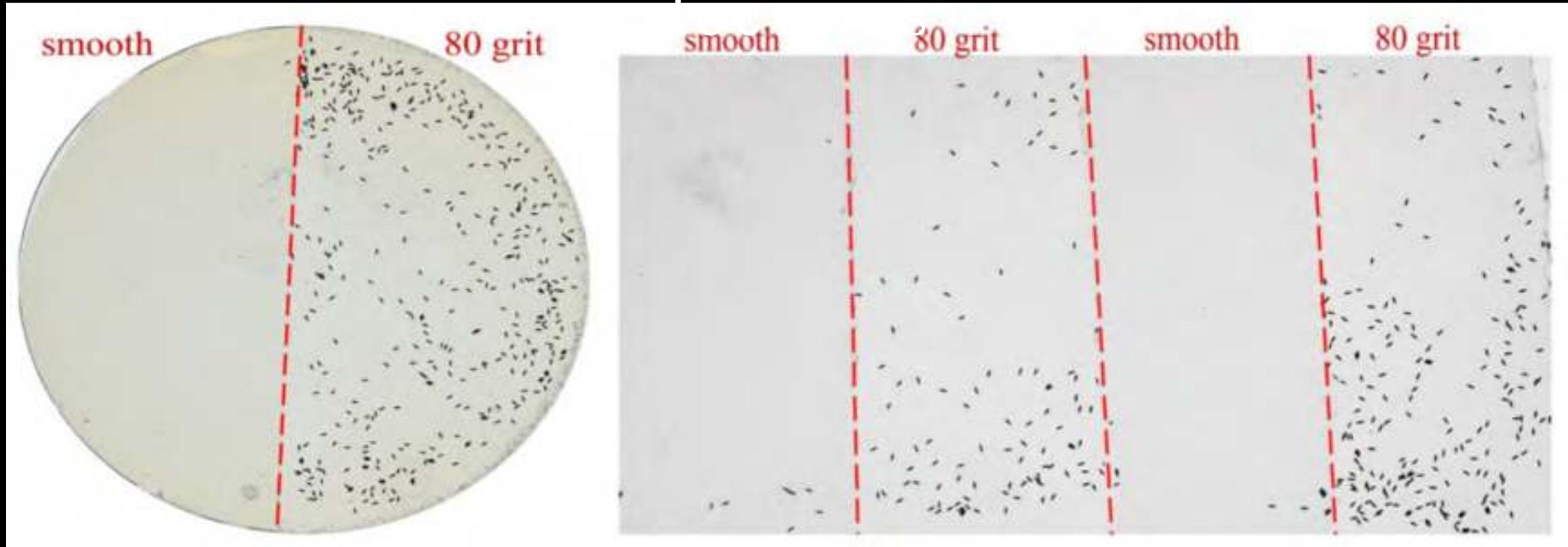
Aedes aegypti females
lay eggs in fresh water to
maximize larval fitness:

Behavior and Physiology
are intertwined

Aedes aegypti



An egg in the rough: surface texture guides egg-laying

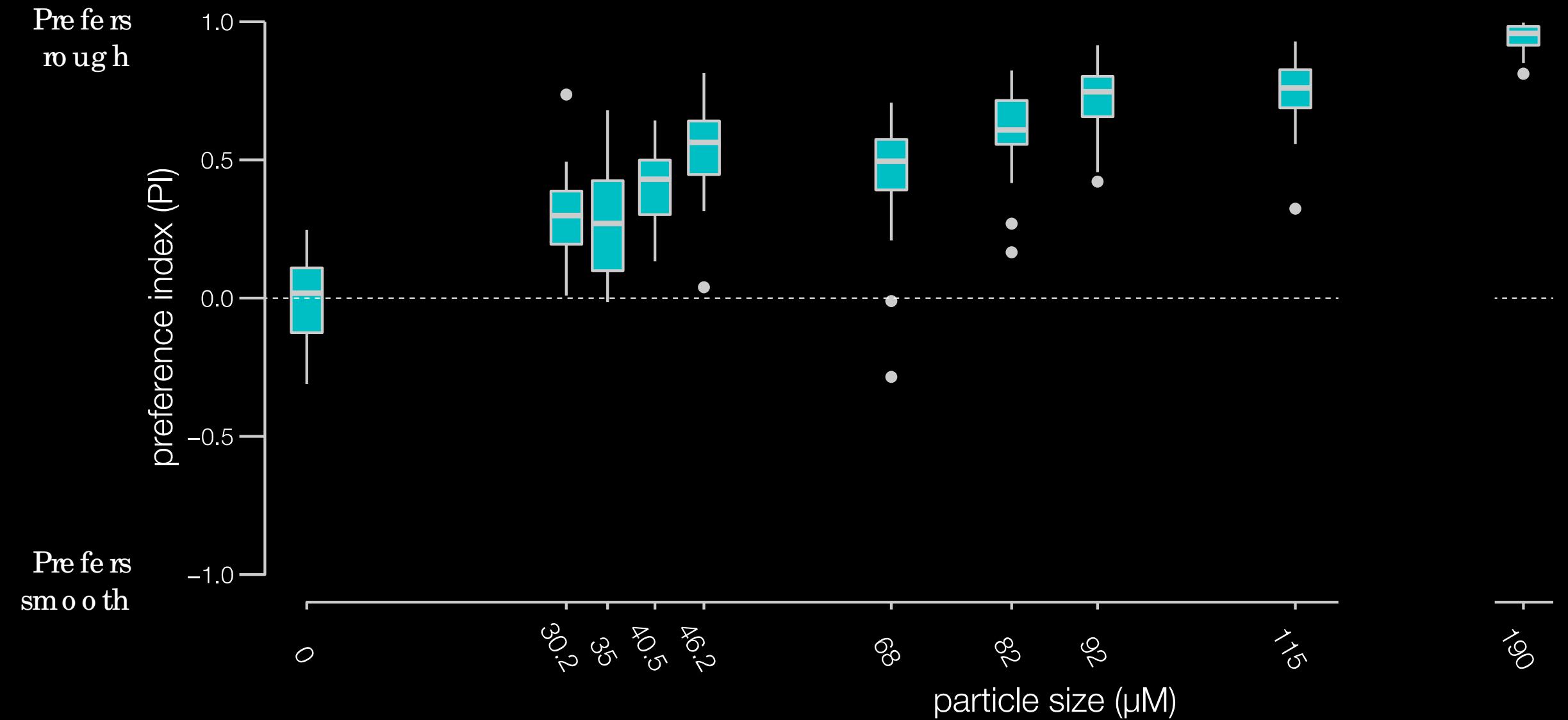


agarose gel patterned with sandpaper



Aleksandra Anoshina, Biology Honours 2020-2021
(w/ all star undergrads Lauren Semko, Annie Zeng, Parisa Seyfouri)

Surface texture guides egg-laying decisions



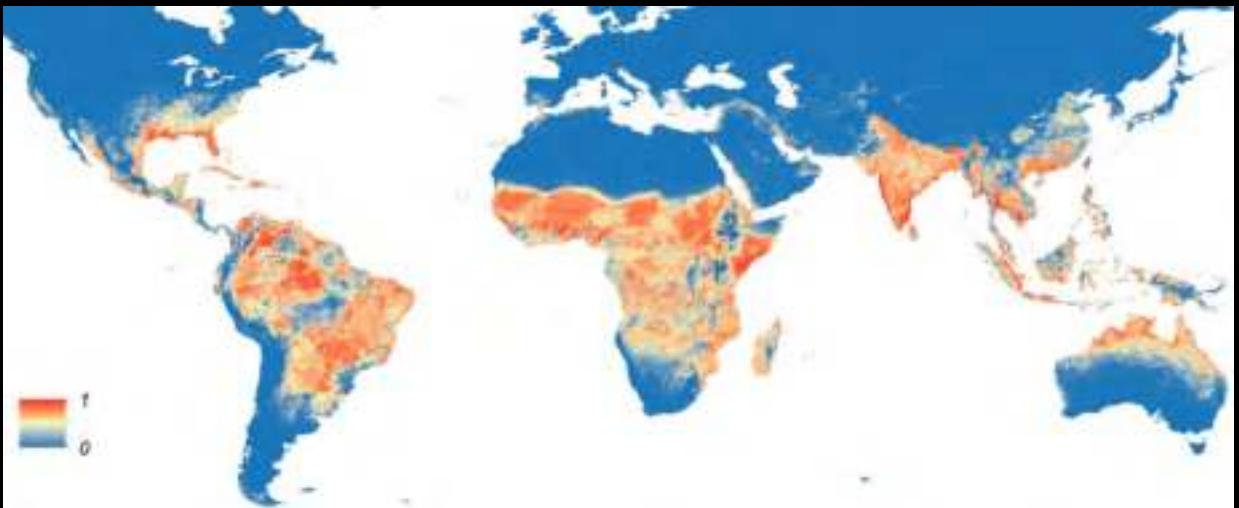
n = 9-26 per condition
ANOVA (Kruskal-Wallis), effect of particle size p < 10⁻²²

particle size (μM)

Aleksandra Anoshina

A comparative approach to understanding behavioral and physiologic adaptations across mosquitoes

*Aedes
aegypti*



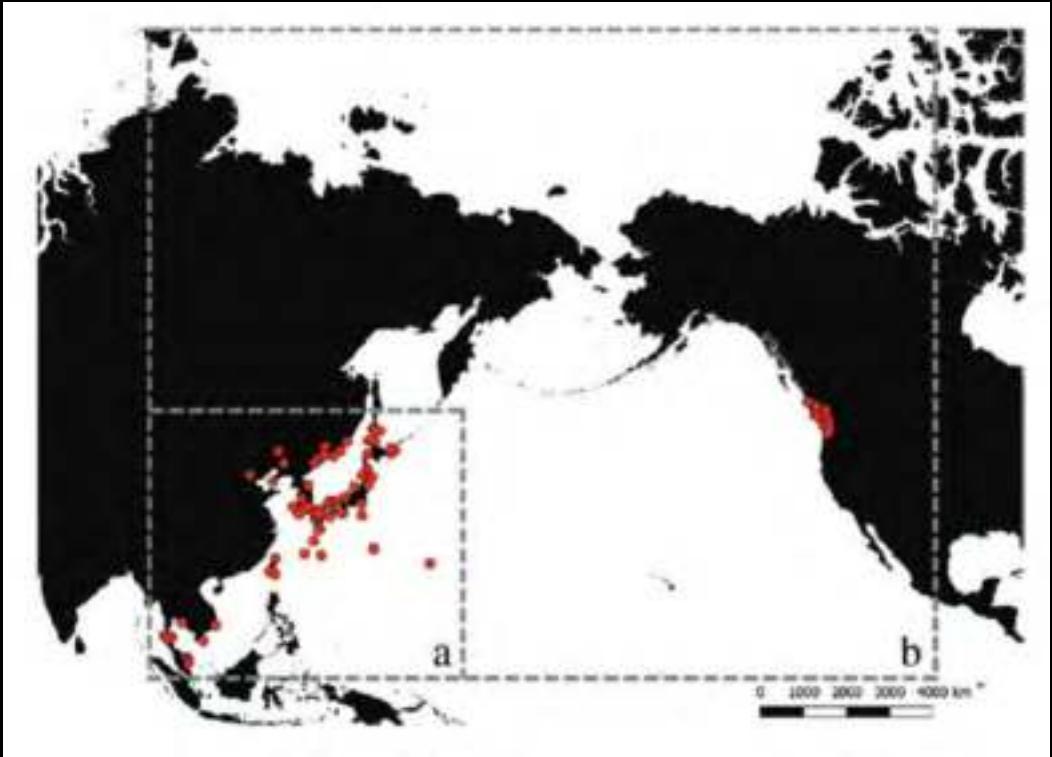
Kraemer et al., 2015

Aedes togoi



A comparative approach to understanding behavioral and physiologic adaptations across mosquitoes

Aedes togoi



Peach and Matthews
bioRxiv 2019; J. Insect Sci. 2020



Aedes togoi mosquito inhabit coastal rock pools



Aedes togoi habitat

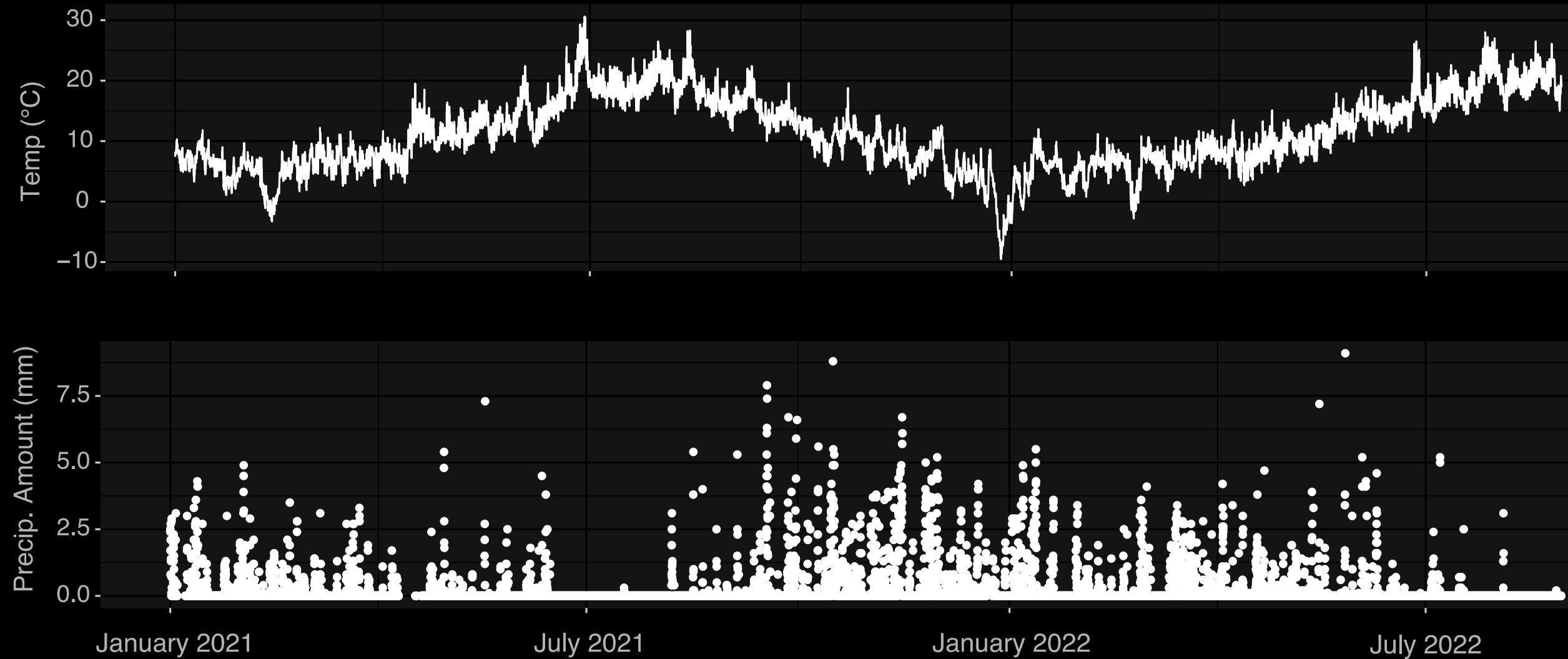


Oma Phelan, M.Sc. student

Aedes to go i fie ld work in Vancouver, Canada



Aedes to go in field work in Vancouver, Canada



British Columbia

More than a billion seashore animals may have cooked to death in B.C. heat wave, says UBC researcher



Shoreline temperatures above 50 C and low tides led to mass deaths of mussels, clams, sea stars



Alex Migdal · CBC News · Posted: Jul 05, 2021 4:36 PM PT | Last Updated: July 6, 2021

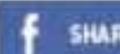


Dead mussels are seen along the shoreline of Third Beach in Vancouver on June 27, in the middle of B.C.'s record-breaking heat wave. (Chris Harley/University of British Columbia)

Canada notches first 40°C temperature of 2022 as high heat persists

Digital Writers

The Weather Network



SHARE



TWEET

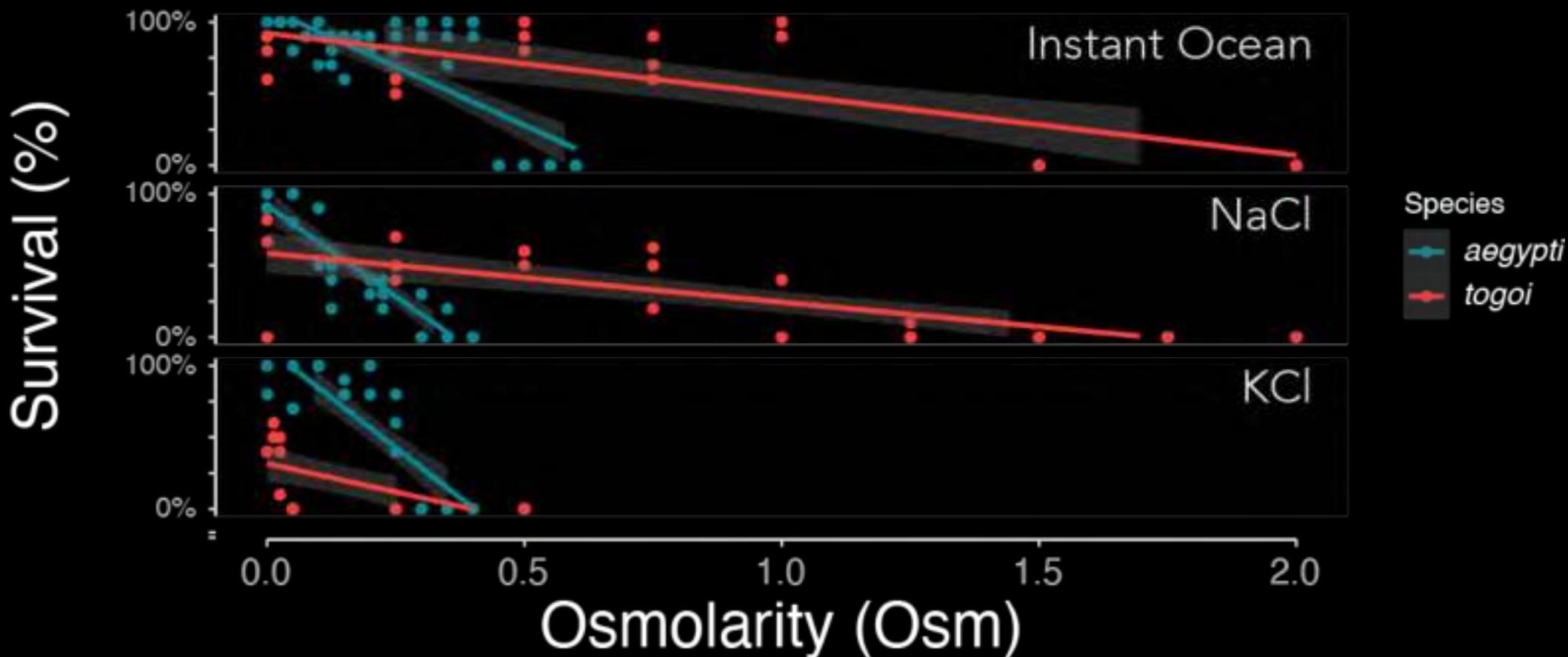
Thursday, July 28th 2022, 4:51 am - A hard-hit town in British Columbia became the first spot in Canada to reach 40°C so far this year—and the heat isn't over yet.

VANCOUVER | News

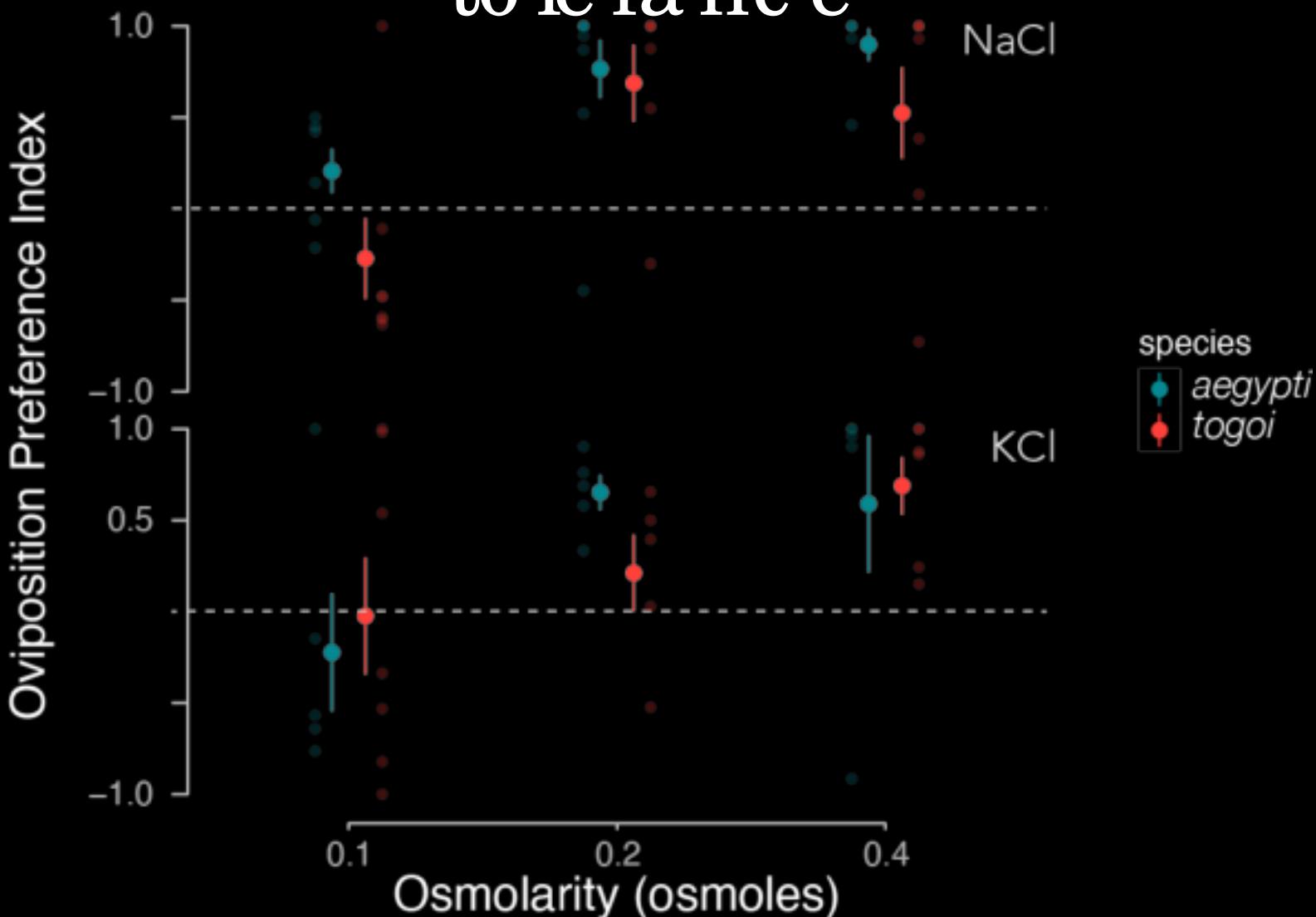
B.C. town breaks 105-year-old temperature record amid cold snap



Aedes togoi larval survival suggests increased tolerance to seawater-like saline solutions



Aedes to go i egg-laying preference does not track with increased physiologic tolerance

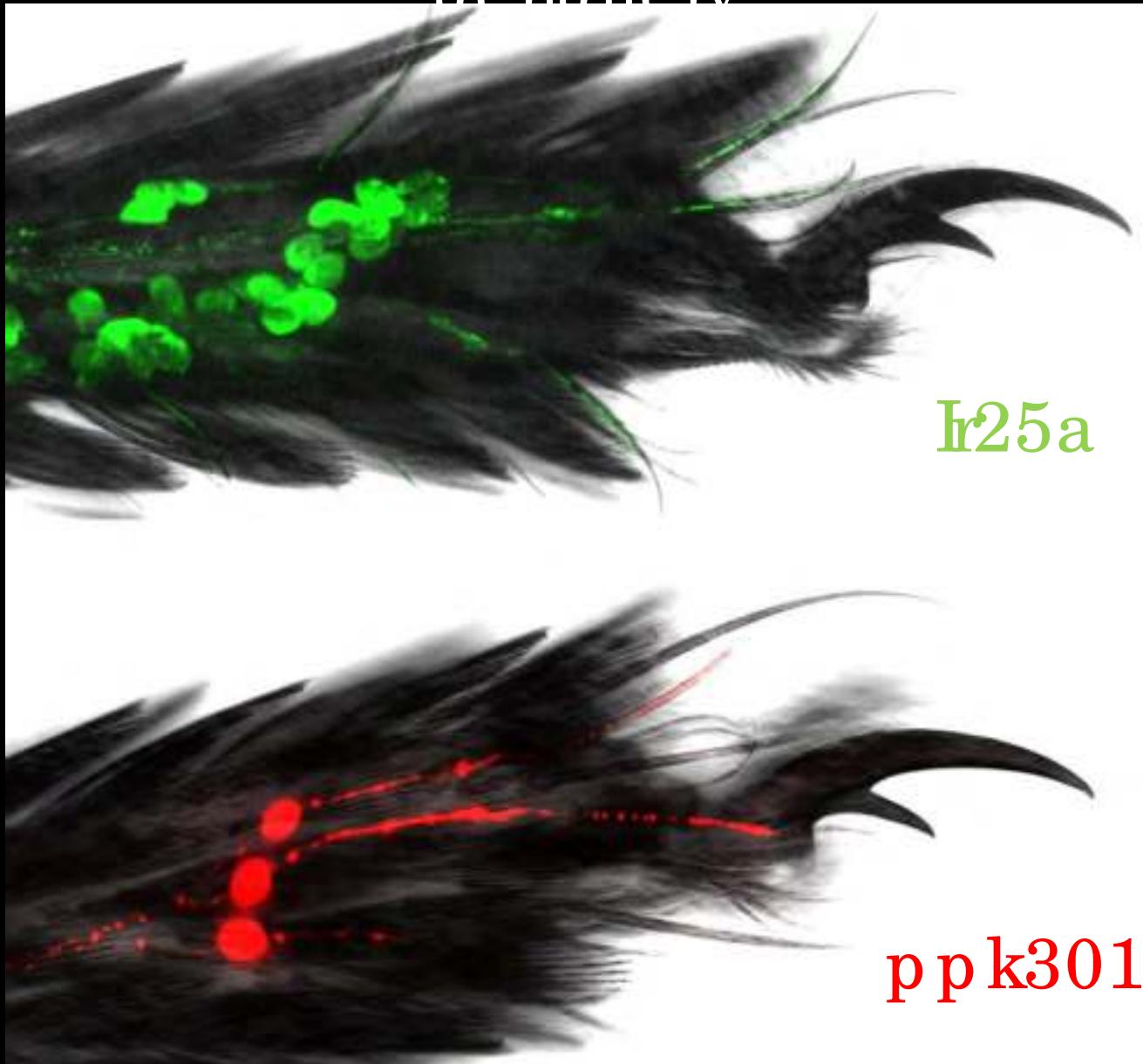


Conclusions: part I

- Mosquito egg-laying behaviour is critical for reproductive fitness and is linked to larval physiology
- *Aedes aegypti* egg-laying is influenced by substrate texture and salt
- *Aedes togoi* mosquitoes inhabit coastal rock pools and can tolerate very high salt concentrations
- *Aedes togoi* egg-laying preference does not change with the same magnitude as larval physiology

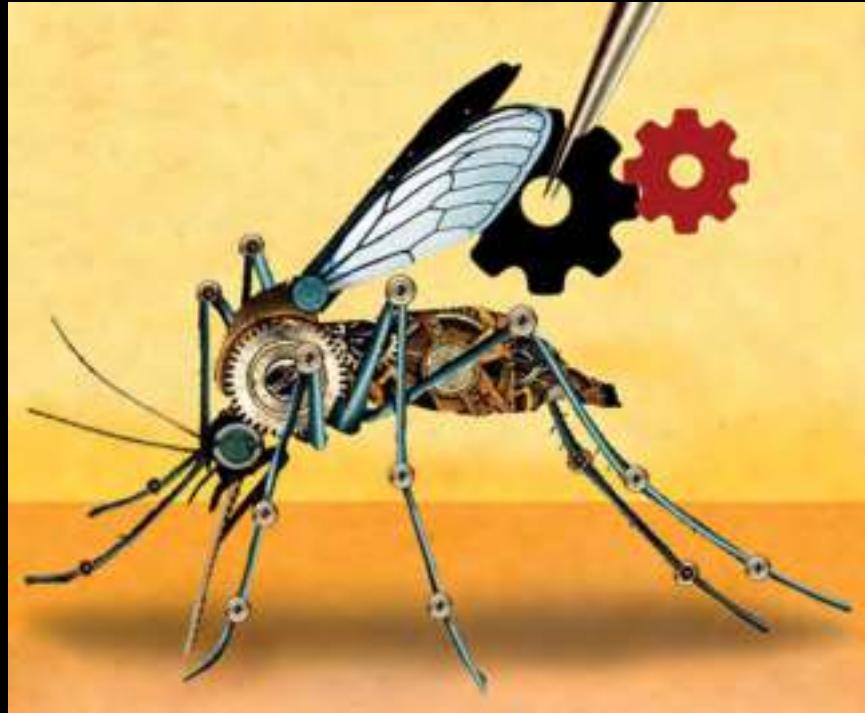
Part II:

Using genetics to determine the logic of taste in the mosquito neuropeprinhe ry



Aedes aegypti is now a tractable genetic system

- Sequenced, assembled and physically mapped genome
- Comprehensive transcriptomic data:
 - Gene expression in specific tissues
 - Genes regulated by behavioral state
- Efficient and precise genome-editing
 - Loss of function mutagenesis
 - Flexible genetic access to specific cell types



Michael Morgenstern

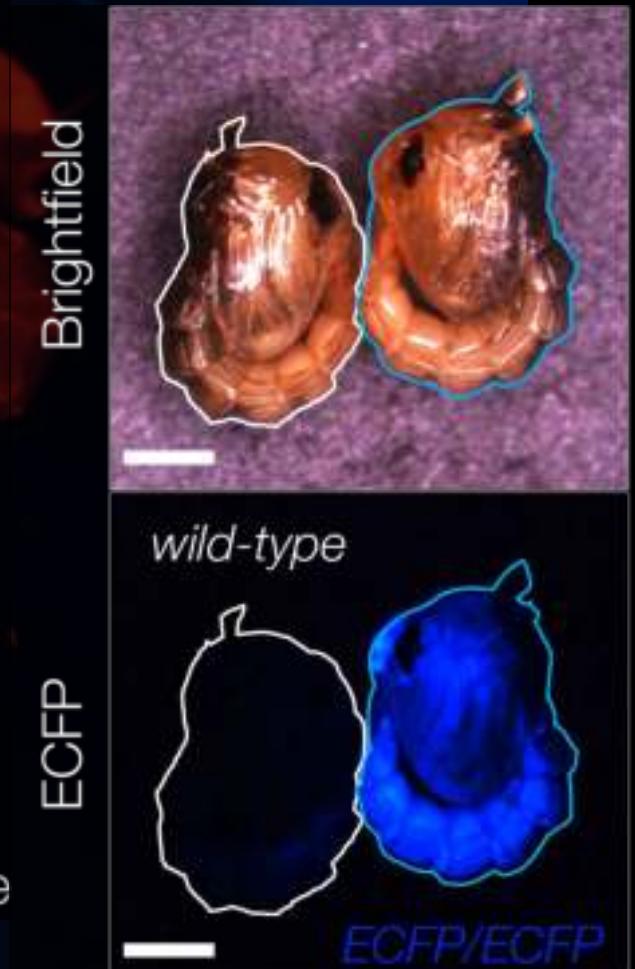
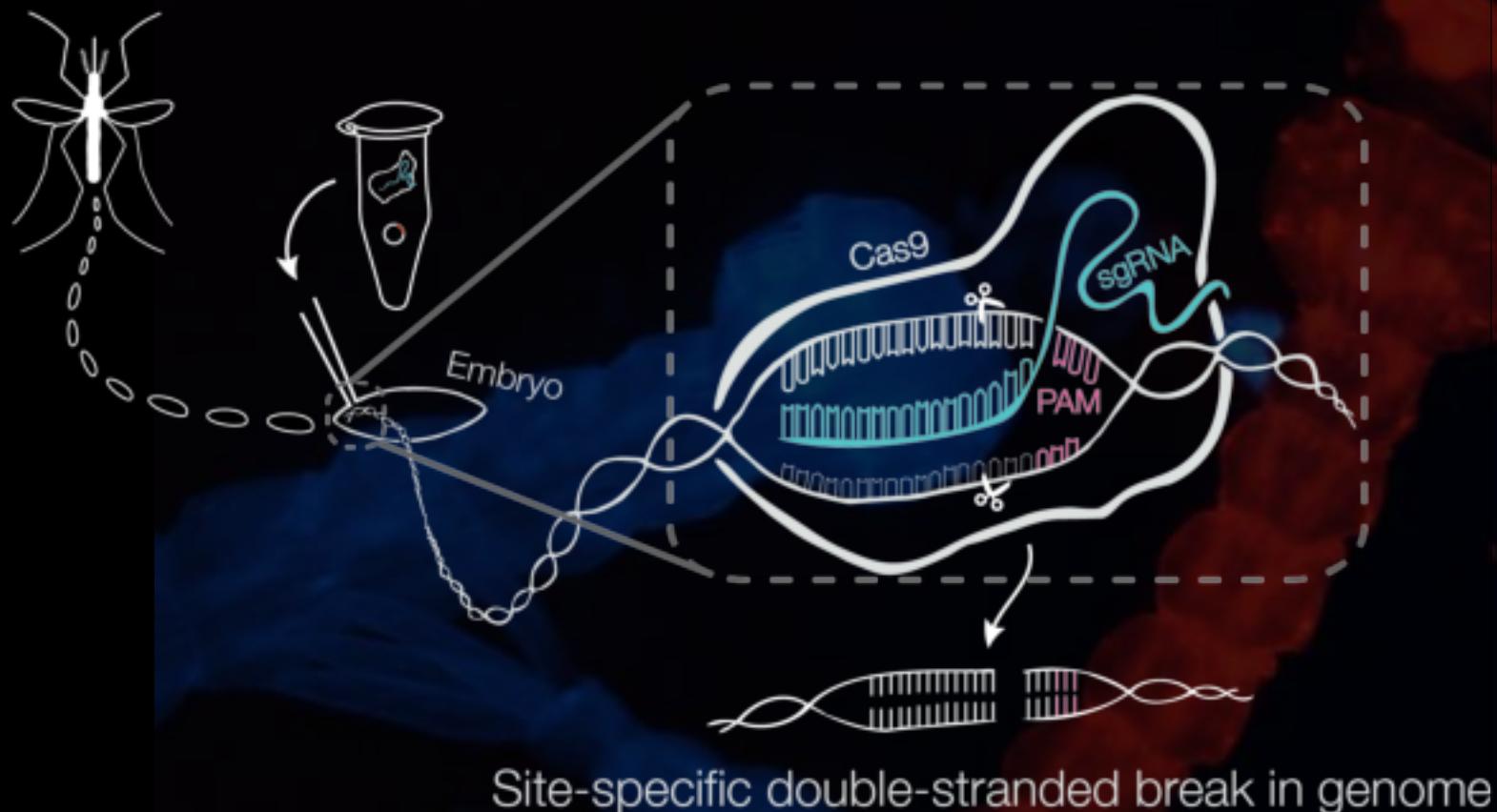
Kistler, Vosshall and Matthews, bioRxiv 2014; Cell Reports 2015

Matthews et al., bioRxiv 2015; BMC Genomics 2016

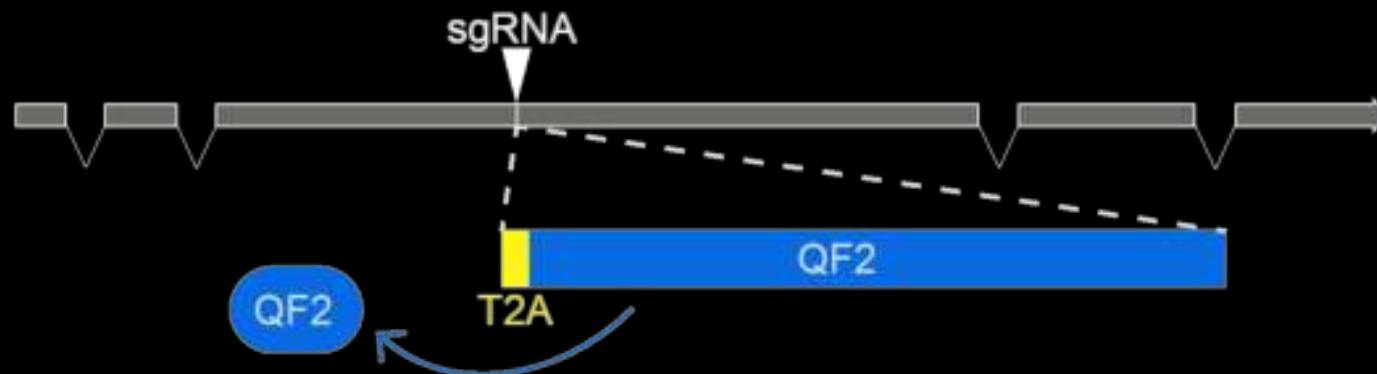
Matthews*, Duchenko*, Kingan* et al. bioRxiv 2017; Nature 2018

Developing a genetic toolkit for non-traditional model organisms

Wild-type *Aedes aegypti* mosquito



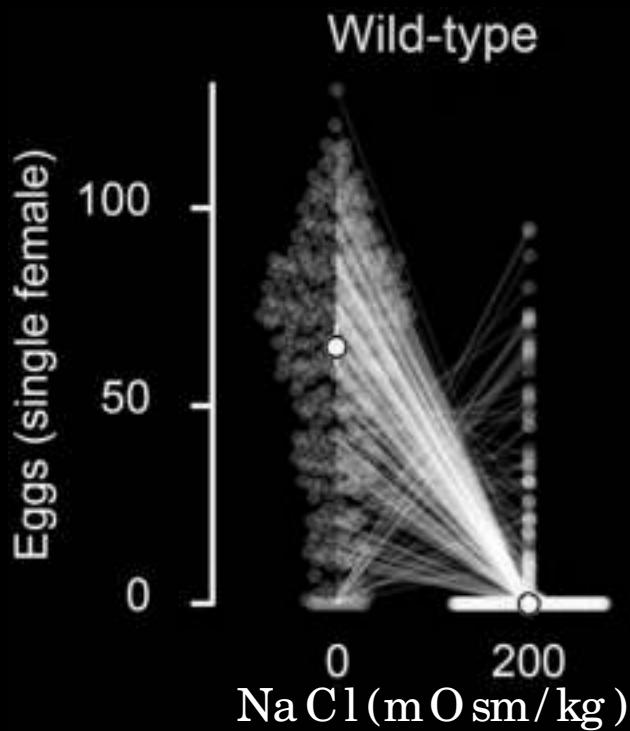
Generating cell-type-specific driver lines with CRISPR/Cas9



Visualize calcium levels that correlate with neural activity

Membrane-tethered GFP
To visualize cellular anatomy

ppk301 mutant mosquito es shows altered fresh/ saltwater choice

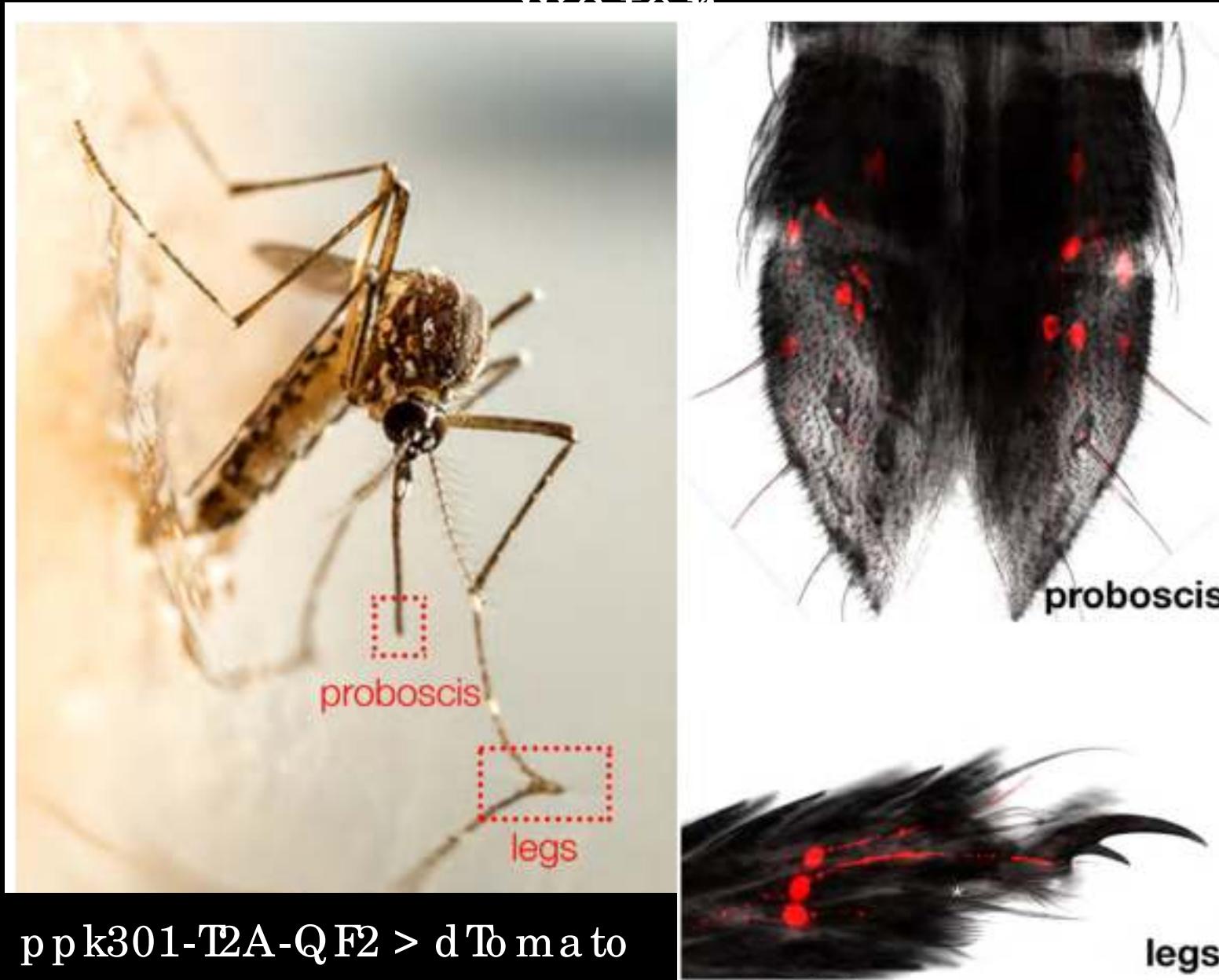


Two-choice egg-laying assay

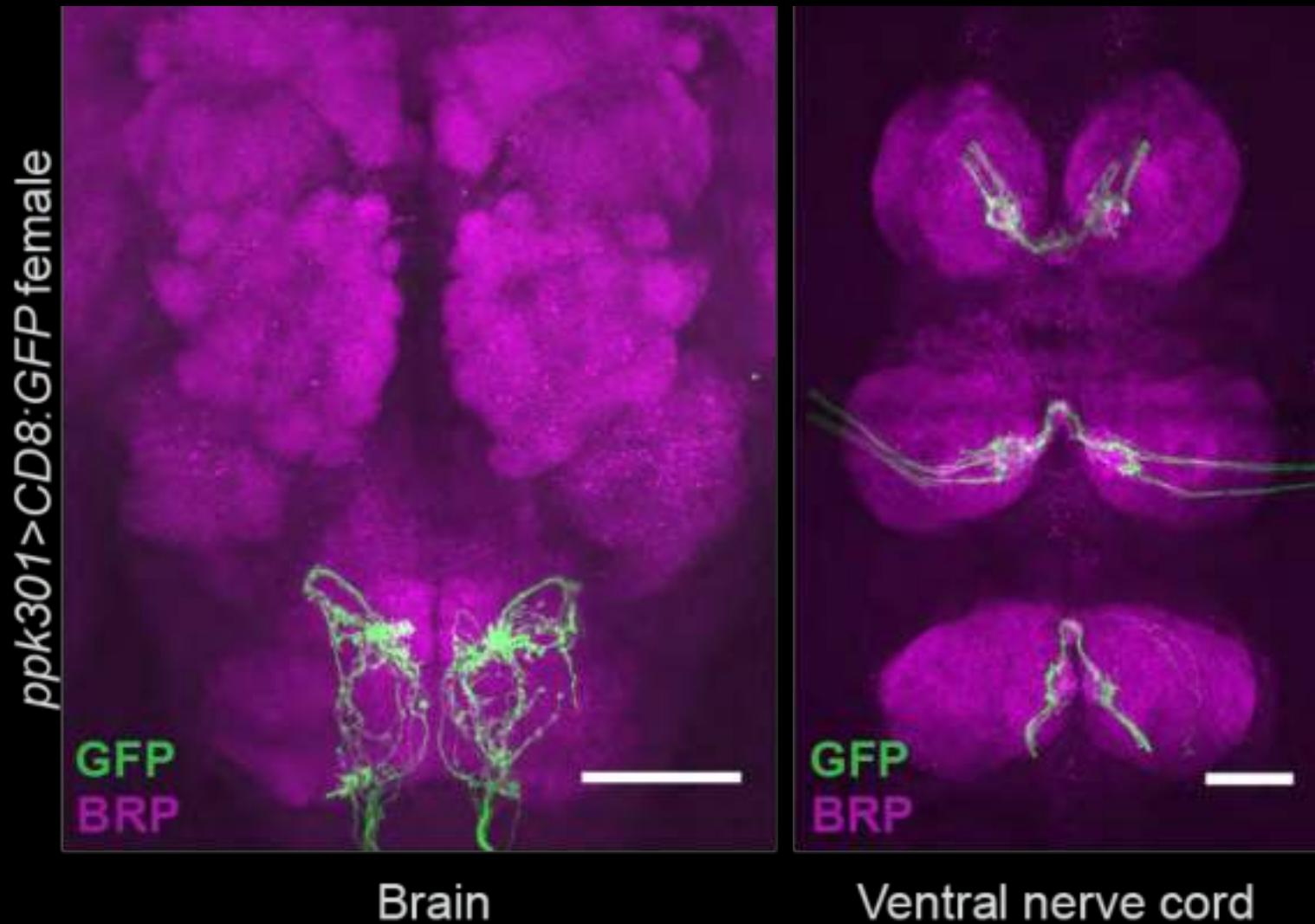
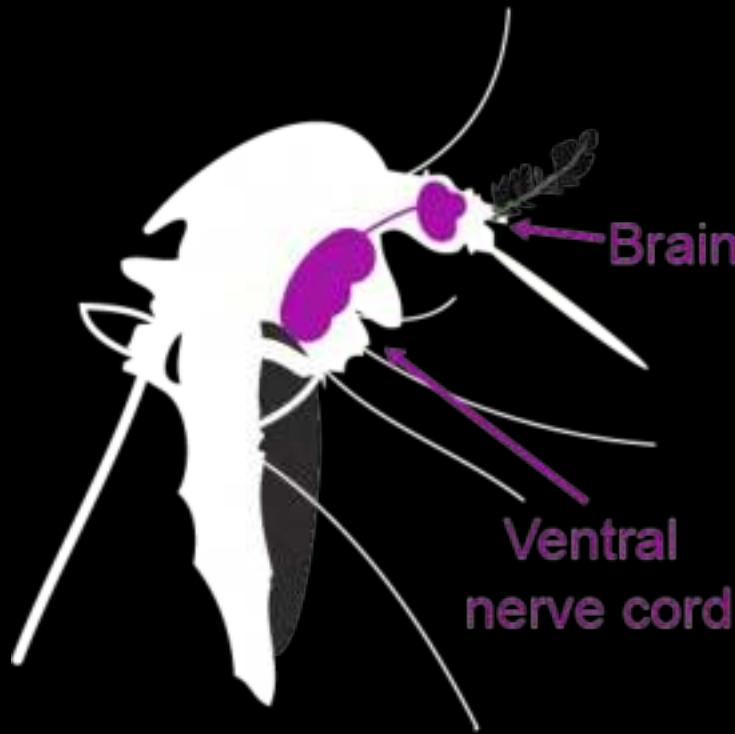
Matthews*, Younger*, Vosshall bioRxiv 2018; eLife 2019

ppk301 is expressed in sensory neurons of tissues that contact

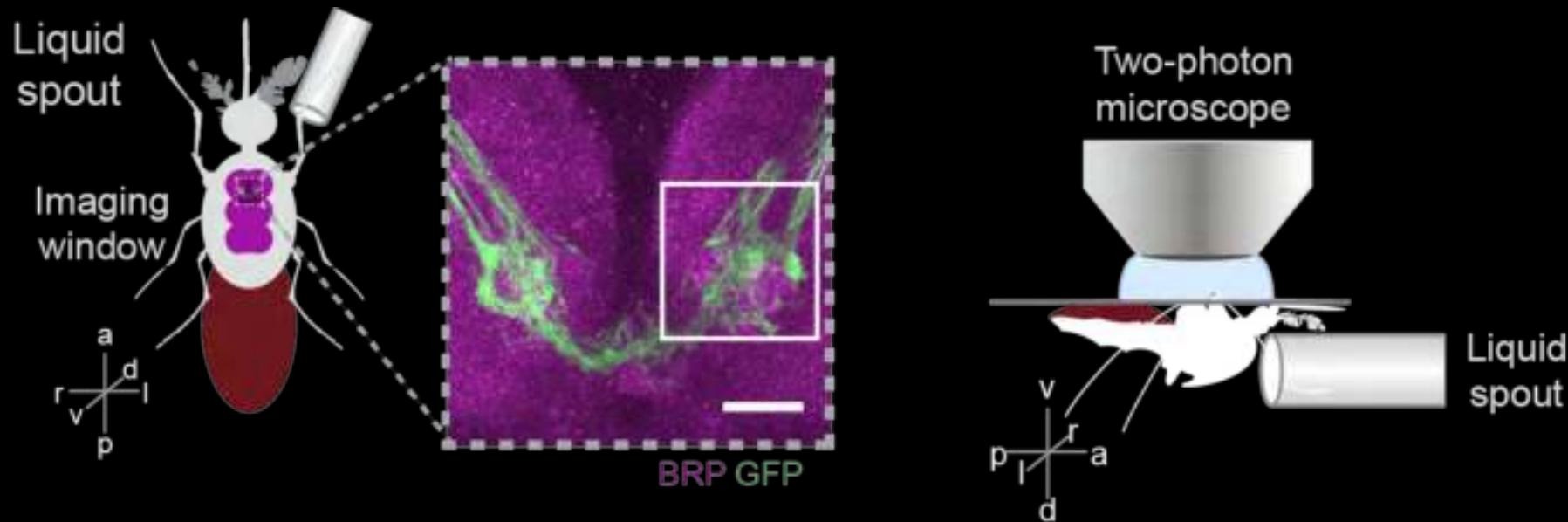
the target



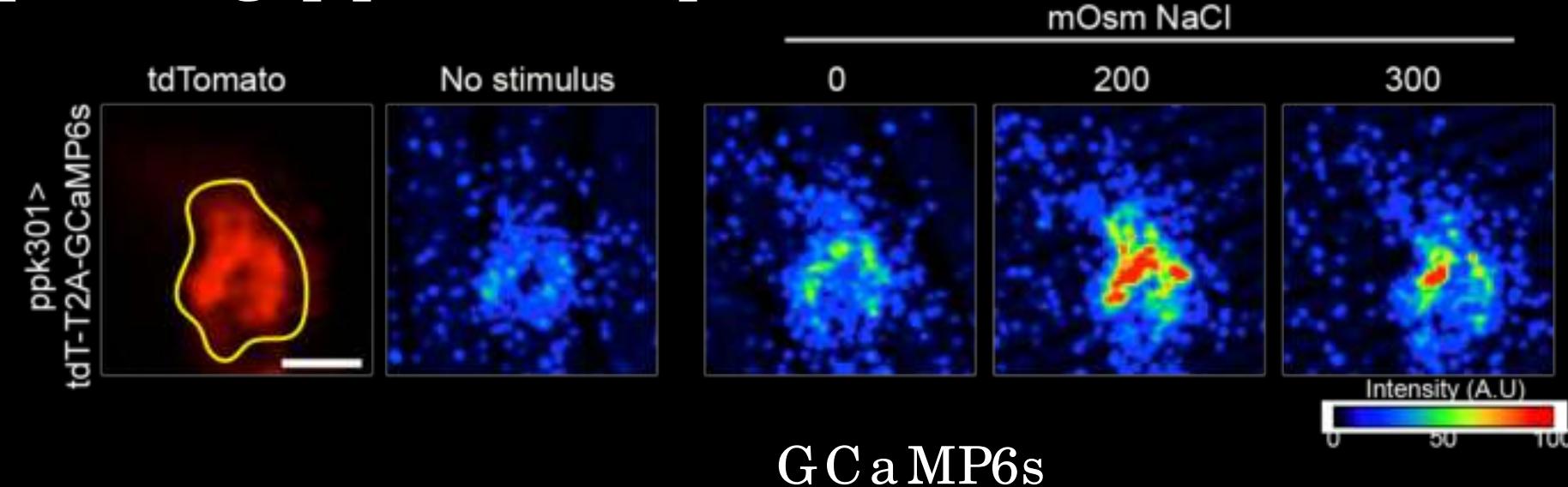
ppk301-expressing sensory neurons project to central taste centers



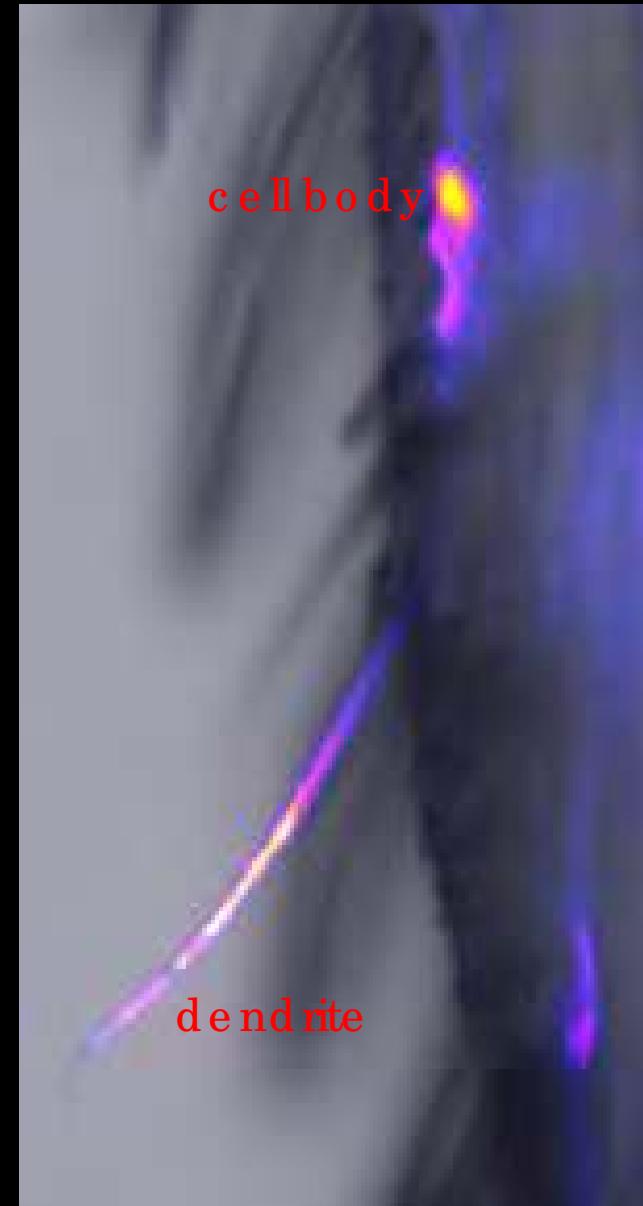
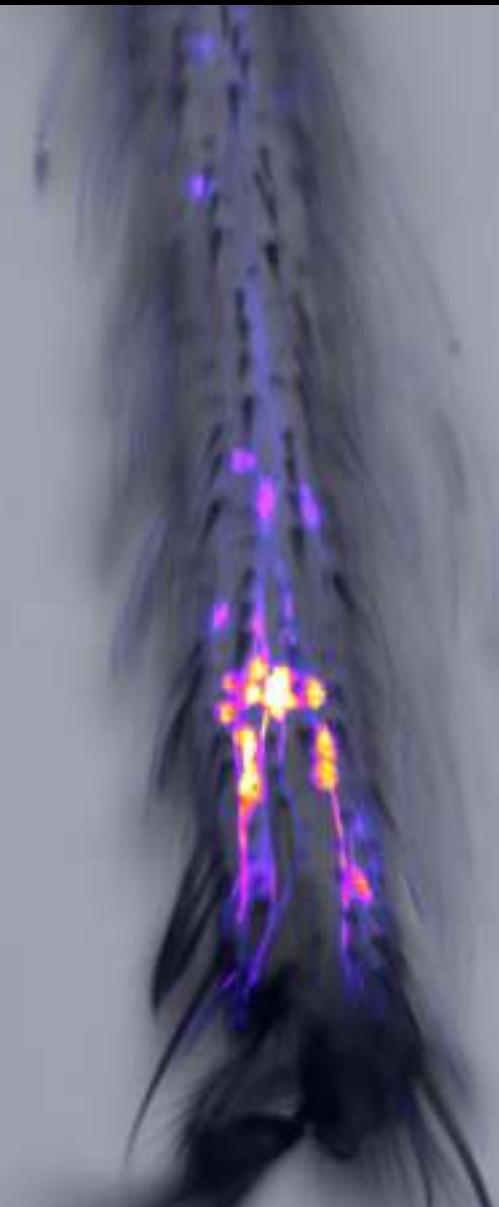
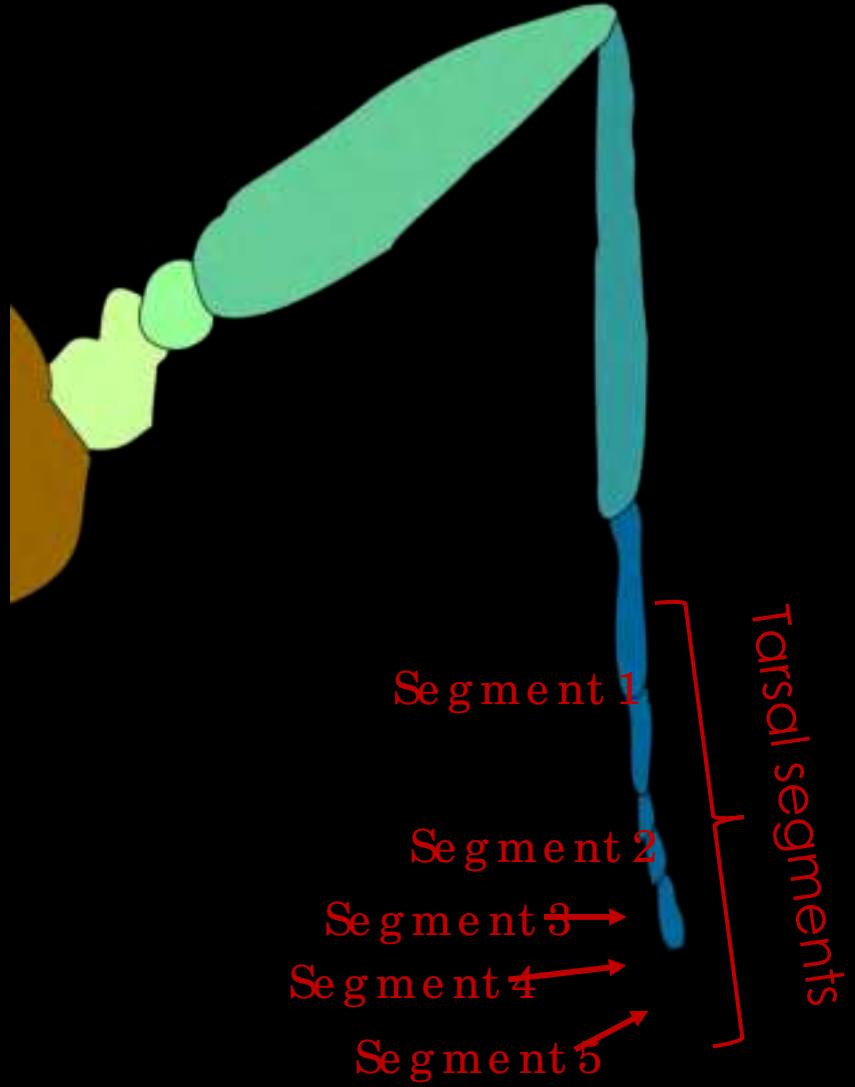
Developing an imaging preparation for mosquito VNC



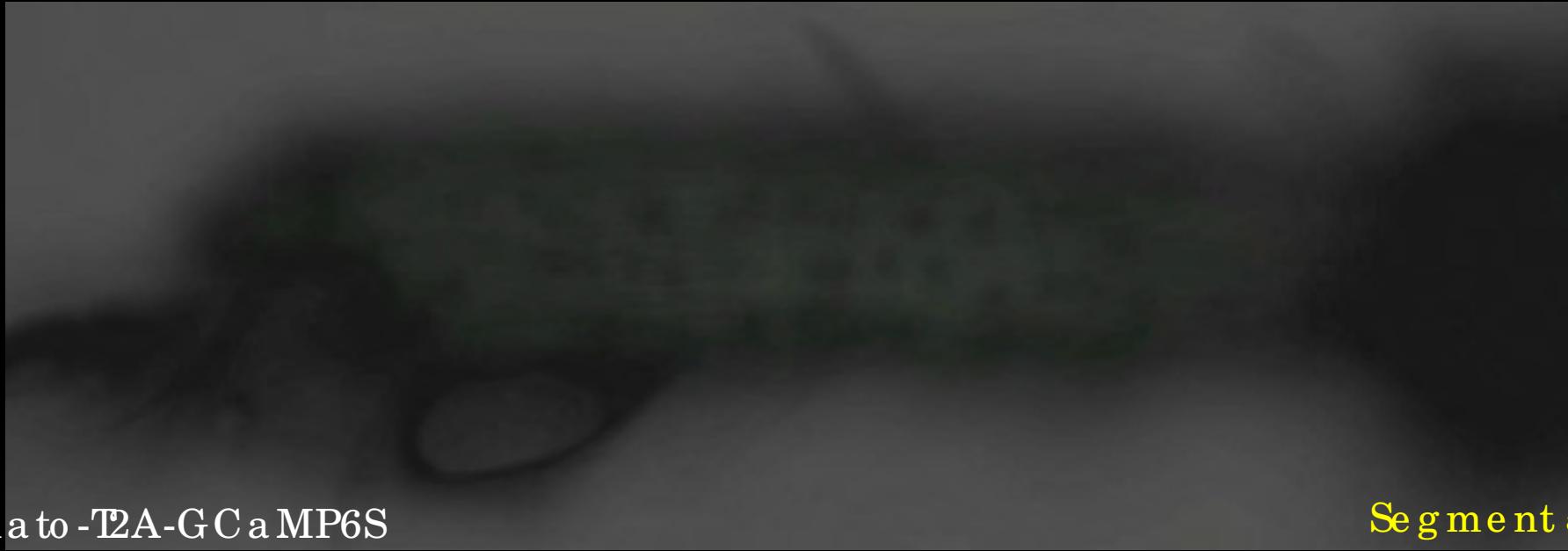
Cells expressing ppk301 respond to freshwater and saltwater



The broader neuroanatomy of *Aedes aegypti* tarsal taste



Elsa Cyr

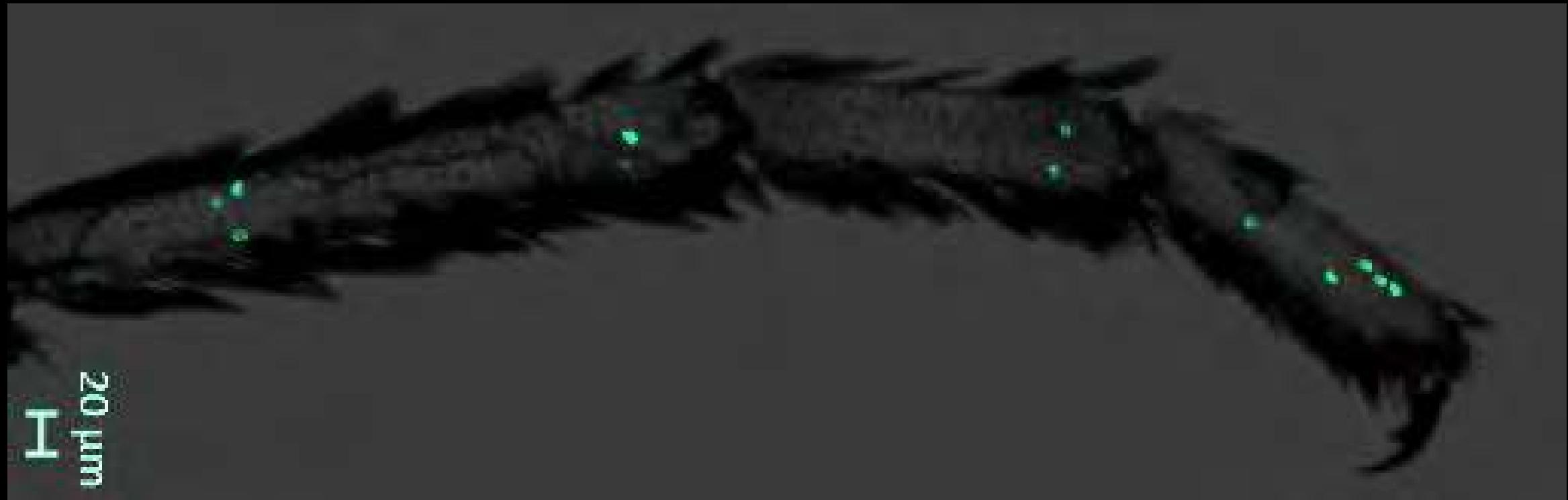


BRP-QF2>d Tomato-T2A-GCaMP6S

Segment 5

Elsa Cyr

Solving a chemosensory puzzle: which receptors are expressed in what cells in the taste system?



Dissect – Isolate – Purify – Sequence



Inspired by the INTACT approach (Henry and Eddy)
and cell-type-specific transcripts of sensory neurons nuclei (McLaughlin, Li and Luo)

Leisl Brewster

Conclusions

- Sensory neurons spread across mosquito tissues convey information about the outside world to inform behaviour
- Mosquito egg-laying behaviour is critical for reproductive fitness
- *Aedes aegypti* egg-laying is influenced by substrate texture and salt
- *Aedes togoi* mosquitoes inhabit coastal rock pools and can tolerate very high salt concentrations
- Genetic tools allow us to profile the anatomy, function, and gene expression of specific sensory neuron cell types



Christmas 2020



Jo shua Chen

Le isl Bre wste r

La ure n Se mko w

Ale ksa nd ra Ano shina

Oma Phelan

Summer 2021



Lauren Semkow

Joshua Chen Annie Zeng

May 2022



Oma Phelan
Joshua Chen
Elsa Cyr
Leisi Brewster

August 2022

Postdocs

Yunusa Mohammed, PhD

Jean-François (Jeff) Doherty, PhD

Graduate Students

Leisl Brewster

Elsa Cyr (with Mike Gordon)

Oma Phelan

Ivan Lo

Tahnee Ames (with Phil Matthews)

Undergraduates

Alexandria Anoshina

Lauren Semkow

Annie Zeng

Parisa Seyfouri

and more... see lab webpage!

Staff

Nick Tocino



THE UNIVERSITY OF BRITISH COLUMBIA

mosquitolab.zoology.ubc.ca

ben.matthews@zoology.ubc.ca

Collaborators

Mike Gordon (UBC)

Phil Matthews (UBC)

Conor McMeniman (Johns Hopkins)

U. Maryland Insect Transformation Facility



CIHR IRSC
Canadian Institutes of
Health Research



INNOVATION.CA
CANADA FOUNDATION
FOR INNOVATION | FONDATION CANADIENNE
POUR L'INNOVATION



NSERC
CRSNG

ALFRED P. SLOAN
FOUNDATION

Preference index of *Aedes aegypti* (Orlando) females by texture

