Insect chemosensory receptors: contribution to plant-insect relationship

Emmanuelle Jacquin-Joly
emmanuelle.joly@inra.fr

INRA SCIENCE & IMPACT

UPMC SORBONNE UNIVERSITÉS

iEES Paris

Sensory ecology department

Insect chemical ecology, from signal identification to their receptor and behavior characterization

Crop pests

Parasitoids

Disease vectors

Chemical senses of insects





Credit: web

Objectives of our group

✓ **How the insect selects the good chemical information in a complex environment?**

Understanding the peripheral mechanisms

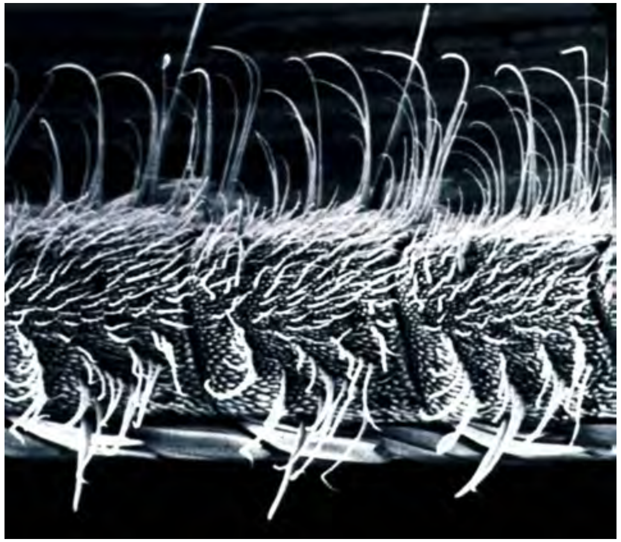
Special focus on chemosensory receptors

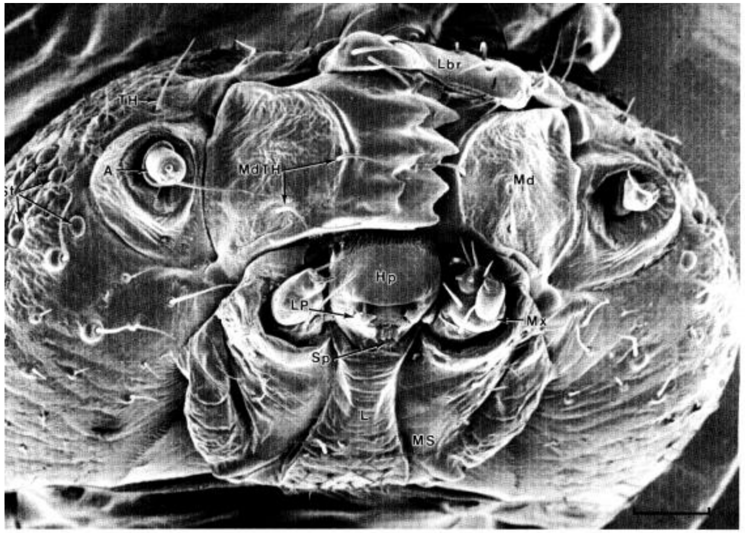
✓**Do and how the chemosensory receptors shape the animal sensory ecology**

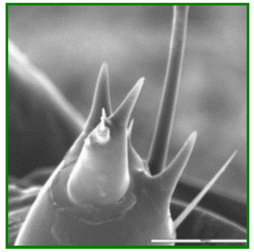
Evolution of gene families

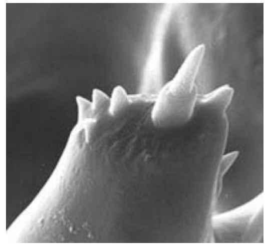
✓ **Identification of receptors as new targets for pest controls**

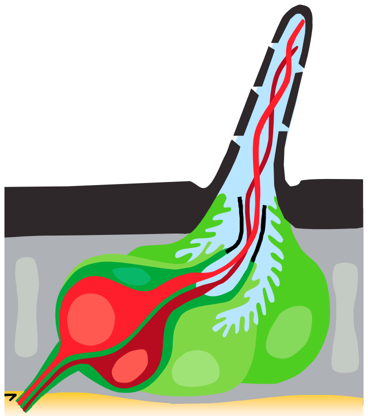
A morpho-functional unit: the chemosensory sensilla



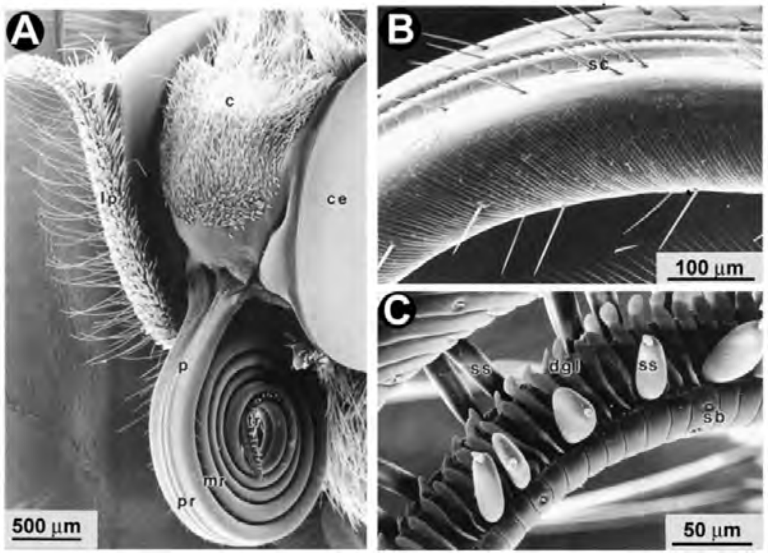


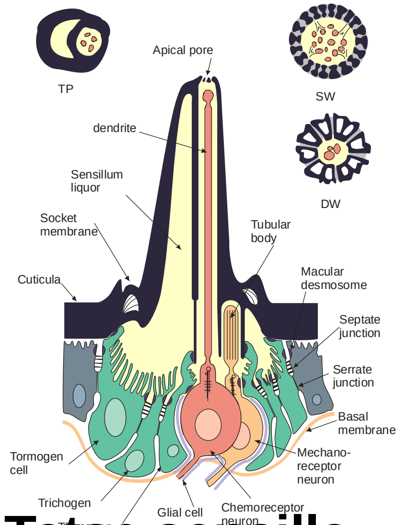






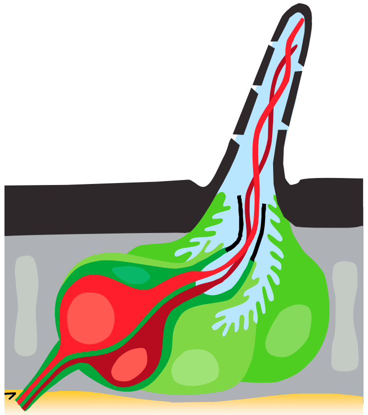
Olfactory sensilla

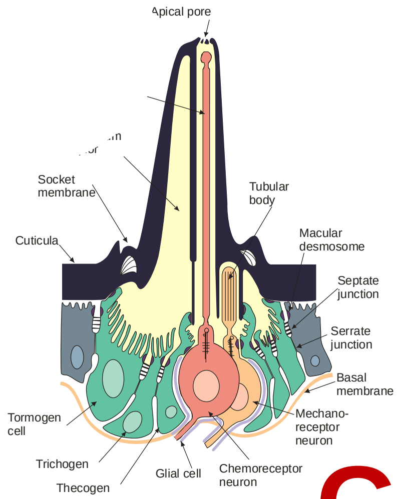




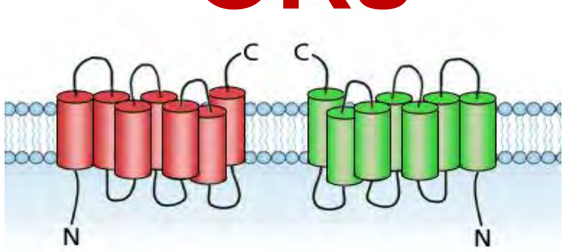
Tatse sensilla

Insect chemosensory receptor families





ORs

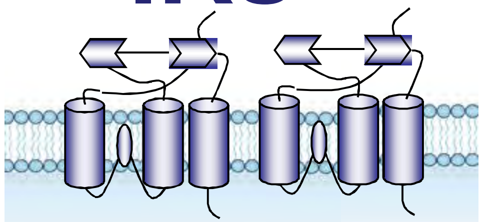


odorant receptor

Co-receptor ORco

Odors
pheromones

IRs

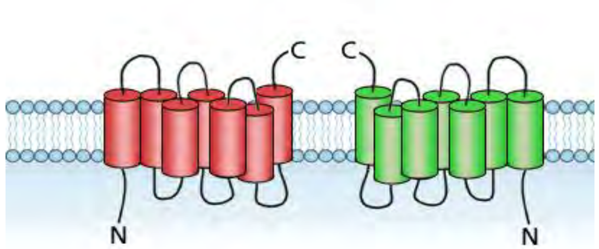


Co-receptor IR8a/25a

ionotropic receptor

Fermentation products
acids

GRs



Gustatory receptor

Co-receptor?

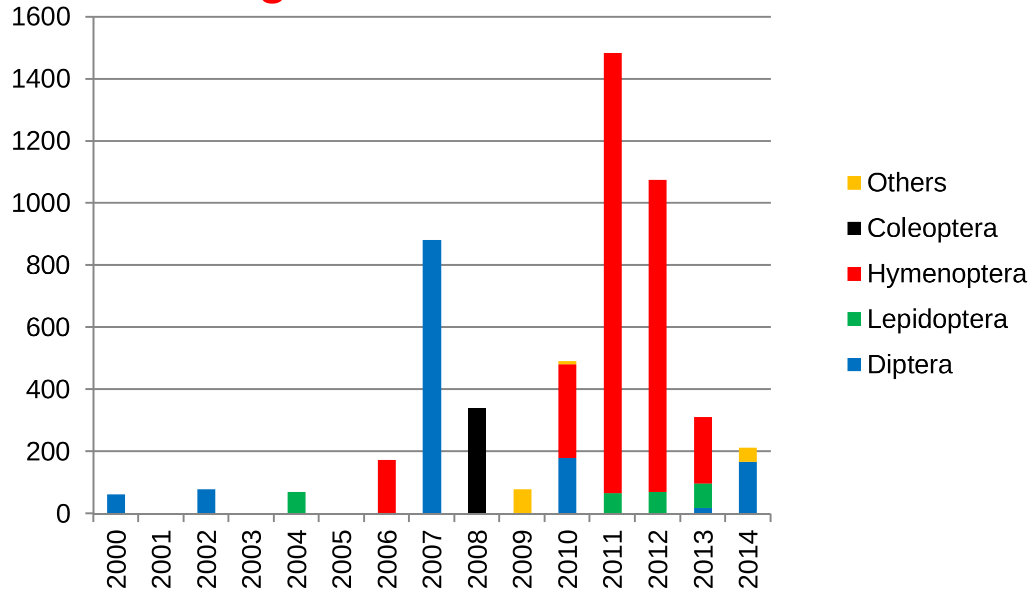
CO2, Sugar
Bitter compounds
pheromones

Development of high-throughput sequencing methodologies:

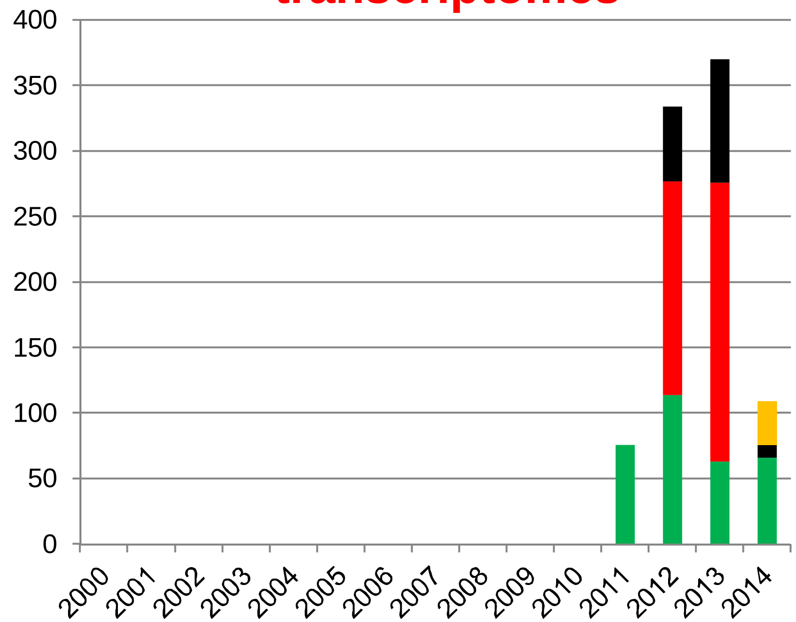
An increasing number of chemosensory gene repertoires from a wide diversity of insect species

Evolution of the number of insect olfactory receptors identified through analysis of

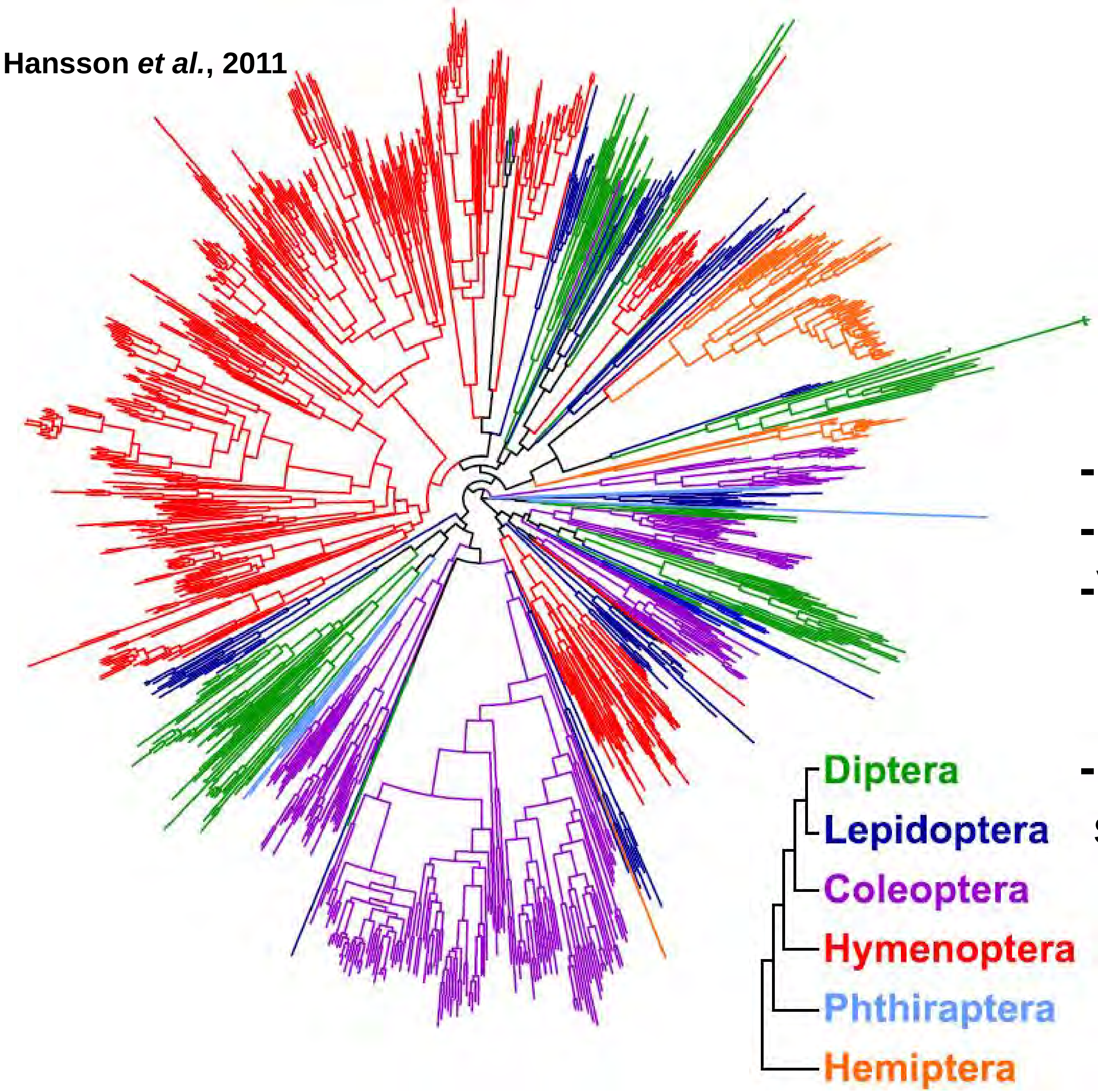
genomes

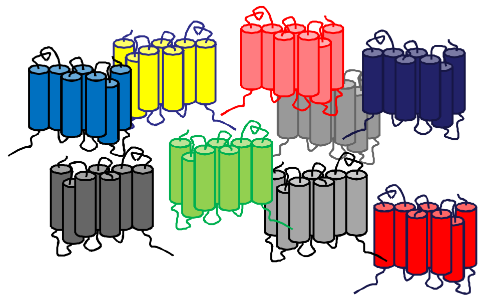


transcriptomes



Montagné et al 2015 Prog Mol Biol Transl Sci





- -10-400 ORs/species
- -Rapidly evolving
- -Very divergent between and within species
- -But most ORs are still orphan receptorsé

How these ORs evolved to adapt to the species ecology?

How a species use its OR repertoire to deal with its environment?

Large OR repertoires have been functionally characterized in only two model species

Drosophila melanogaster

Anopheles gambiae

Although diverse, Diptera can not resume insect chemical ecology

The cotton leafworm
Spodoptera littoralis (Noctuidae)
a model species for herbivores

-highly polyphagous crop pest
-a strong background on olfactory behaviors and physiological properties of olfactory neurons
-a long list of molecules known to be active on either behavior and/or antennae
-48 Ors identified via transcriptomics

Legeai et al 2011, BMC G
Jacquin-Joly et al 2012, IJBS
Poivet et al 2013, PloS One

The curent challenge:
development of functional genomics in non model insects

➡ ***Heterologous expression:***
deorphanization of ORs

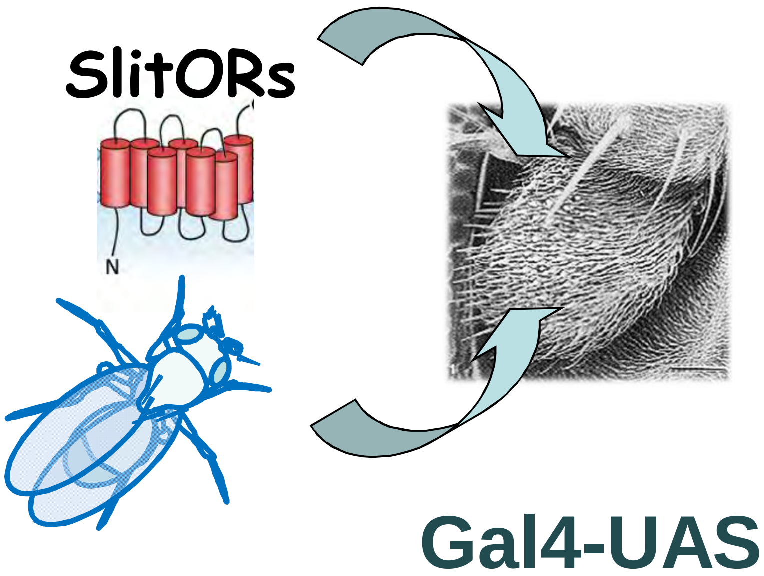
➡ ***Reverse genetic:***
development of genome editing

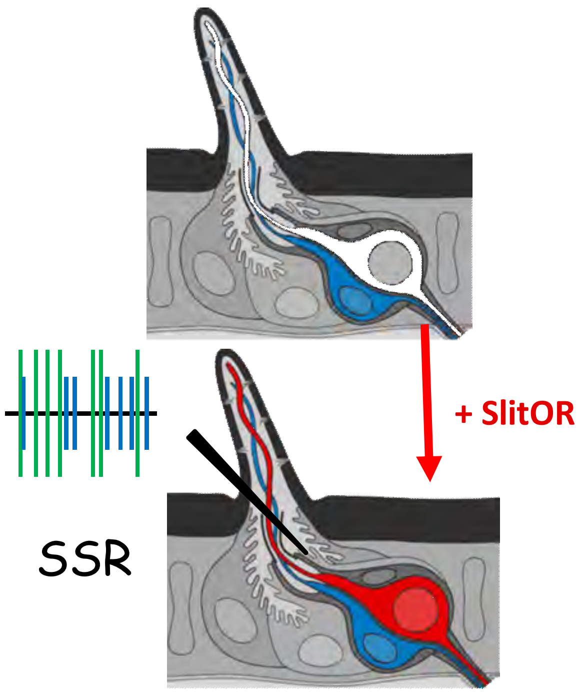
OR deorphanization

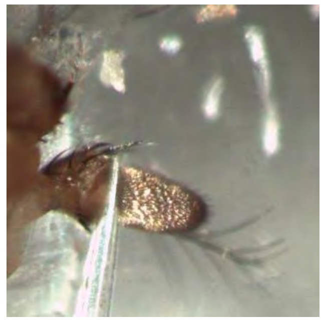
using the *Drosophila* « empty neuron »

iEES Paris

SLU







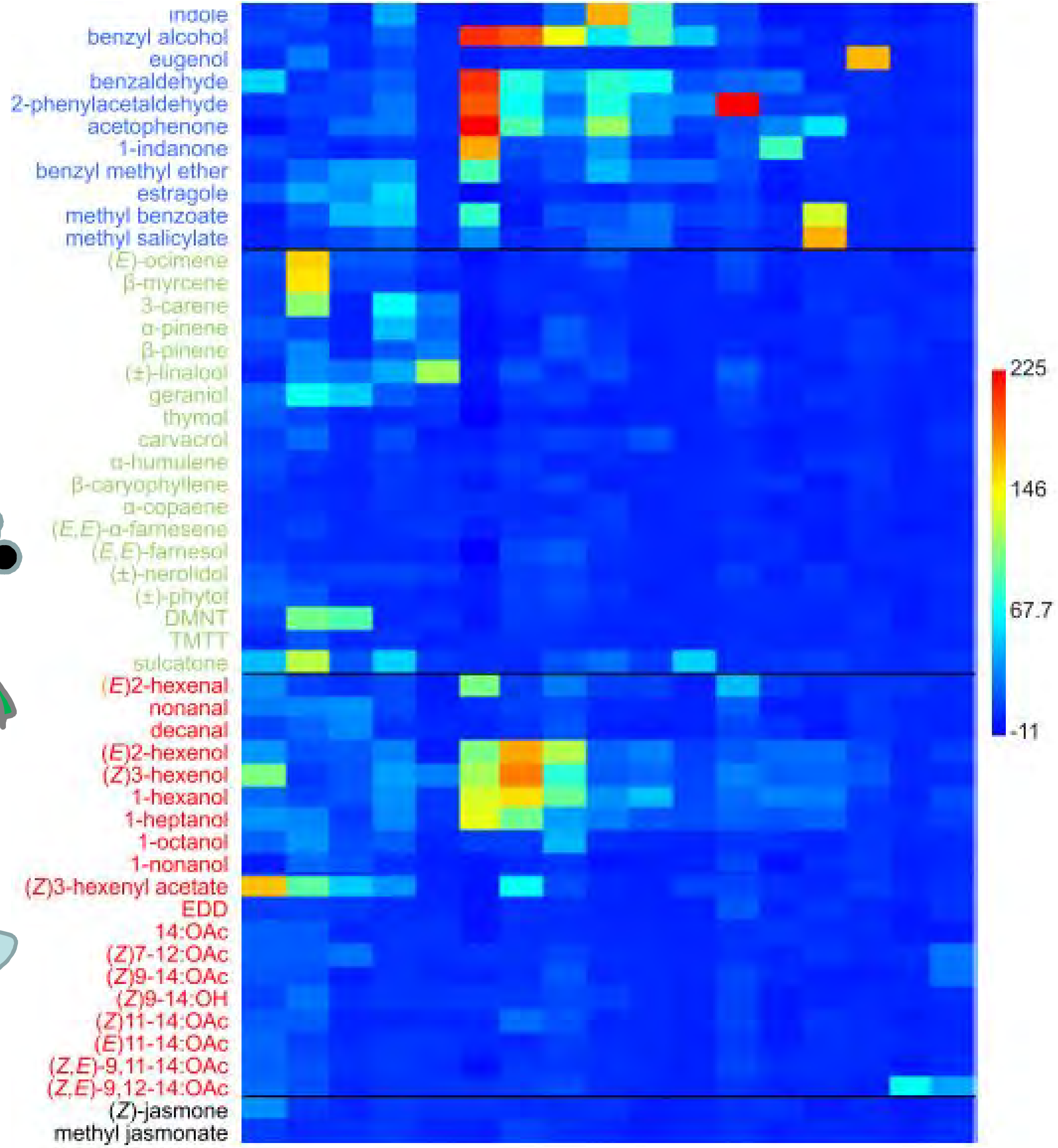
Montagné et al 2012 Eur J Neurosci
De Fouchier et al 2015 Front Ecol Evol
De Fouchier et al submited

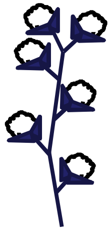
Hallem et al 2004 bs
Kurtovick et al 2007 ts

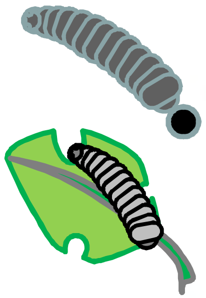
A. De Fouchier

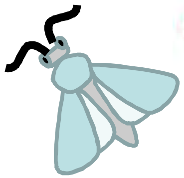
EcoSens SLU

SlitORs







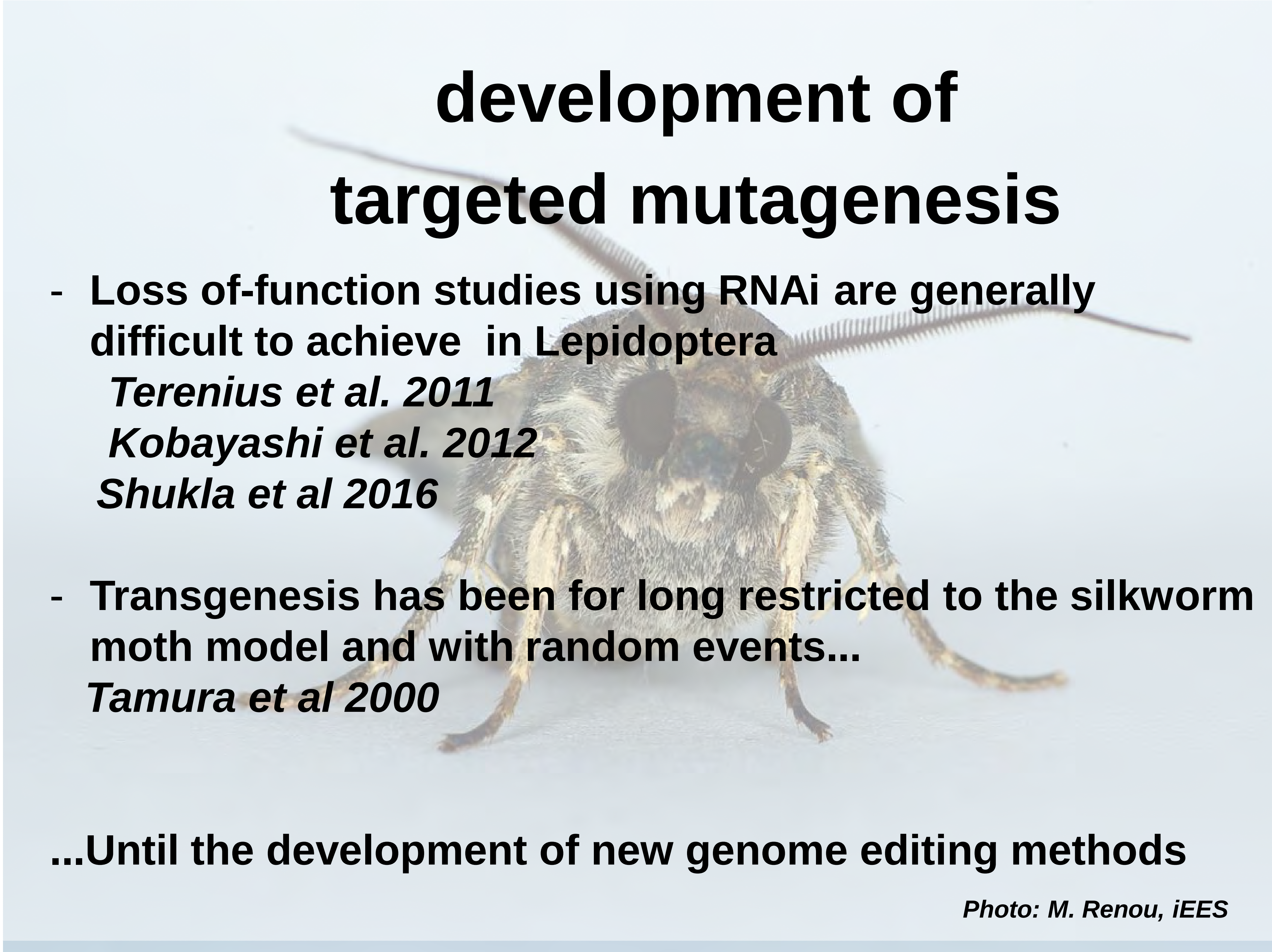


One OR can recognize several odorants

One odorant can be recognize by several ORs

De Fouchier et al submited

De Fouchier et al 2015 Front Ecol Evol



development of targeted mutagenesis

- **Loss of-function studies using RNAi are generally difficult to achieve in Lepidoptera**
  Terenius et al. 2011
  Kobayashi et al. 2012
  Shukla et al 2016

- **Transgenesis has been for long restricted to the silkworm moth model and with random events...**
  Tamura et al 2000

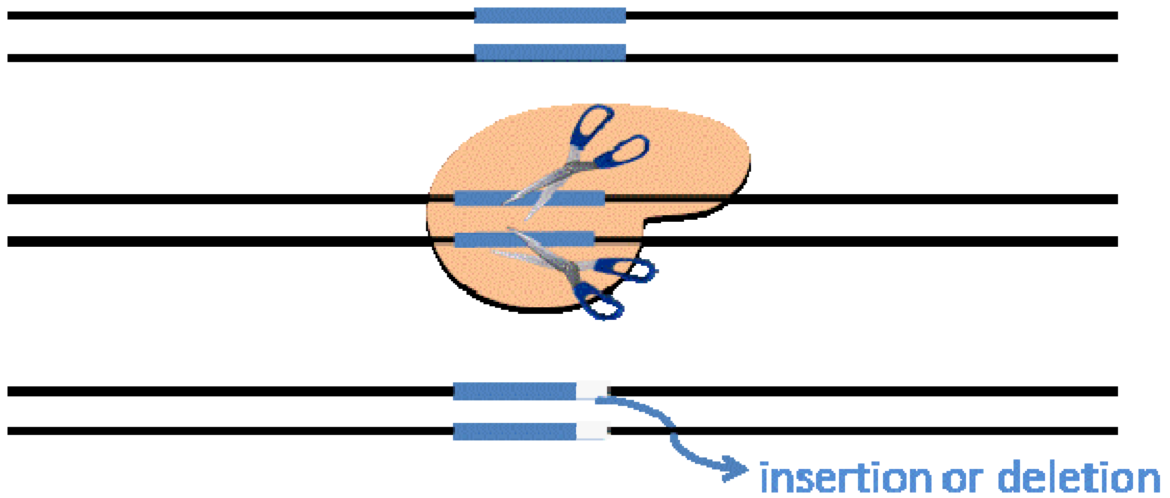
...Until the development of new genome editing methods

Photo: M. Renou, iEES

Genome engineering by targetable nucleases

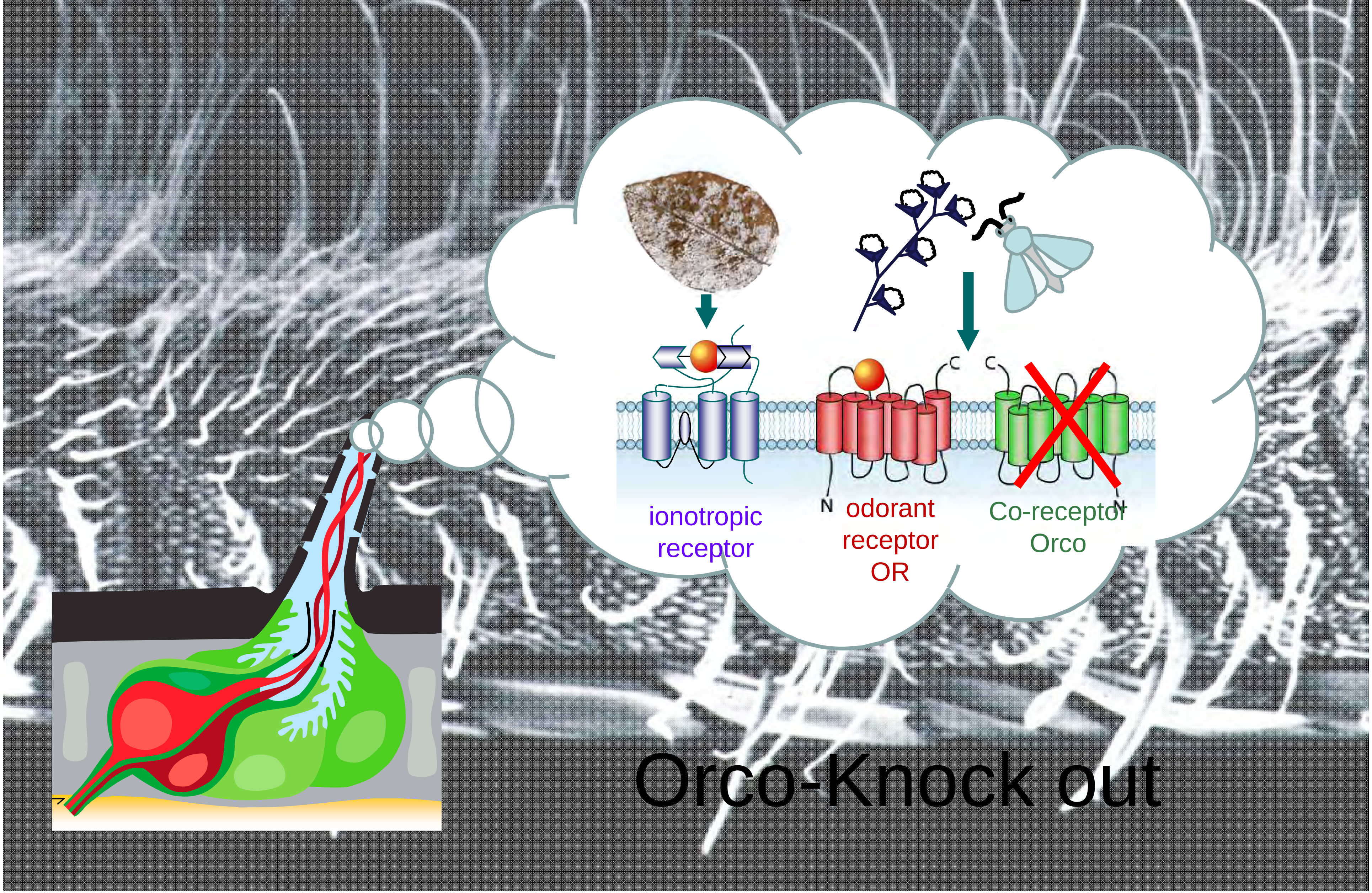
ZFN	Zinc finger nuclease
TALEN	Transcription activator-like effector nuclease
CRISPR/Cas9	Clustered Regularly Interspaced Short Palindromic Repeats

induce specific breaks in DNA whose repair either induces local mutations or stimulates homologous recombination



A challenge in non-model Lepidoptera   But recent developments

Insect olfactory receptors



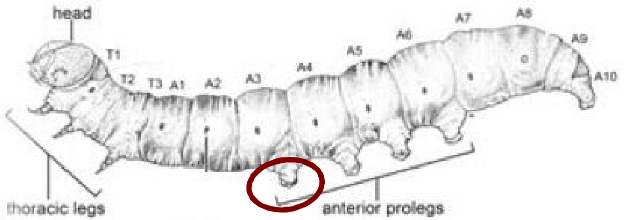
Orco-Knock out

F. Koutroumpa

C. Monsempes

MC. François

GO Genotyping -results




```
F1-29.1.1.. GCGATTCTCATCACCATACATTTTGCCTGTAAGGAACGTTAAAAAATTACACAGAAAATTAGTATGGTATGGTAGGTAGCACAC 56+
F1-30.3.11  GCGATTCTCATCACCATACATTTTGCCTGTAATACAGGTATCATACATTCTGCCAGGGTATCAACATGGCCCAGTACTCCGATG 24
F1-31.3.6   GCGATTCTCATCACCATACATTTTGCCTGTATSRRYATSTTTGGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCT 10
F1-29.1.2   GCGATTCTCATCACCATACATTTTGCCTGTATSCTGCCTGGGTATCAACCTGGCCCAGTACTCCGATGAGGTCAACGAGCTGAC 7
F1-30.3.4.. GCGATTCTCATCACCATACATTTTGCCTGTACTCCGATGGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACT 7
F1-29.1.13  GCGATTCTCATCACCATACATTTTGCCTGTATGGGTATSRGTMWCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACT 6
F1-31.1.9   GCGATTCTCATCACCATACATTTTGCCTTGTGTGGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAA 3
F1-31.1.6   GCGATTCTCATCACCATACATTTTGCCTGTT:GGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAAC 2
F1-30.1.1   GCGATTCTCATCACCATACATTTTGCCTGT::GGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAAC 2
F1-31.1.2   GCGATTCTCATCACCATACATTTTGCCT::::GGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAAC 4
F1-29.1.14  GCGATTCTCATCACCATACATTTTGCCT::::::GTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAAC 6
WT          GCGATTCTCATCACCATACATTTTGCCTGTATGGGTATCAACATGGCCCAGTACTCCGATGAGGTCAACGAGCTGACTGCCAAC WT
```

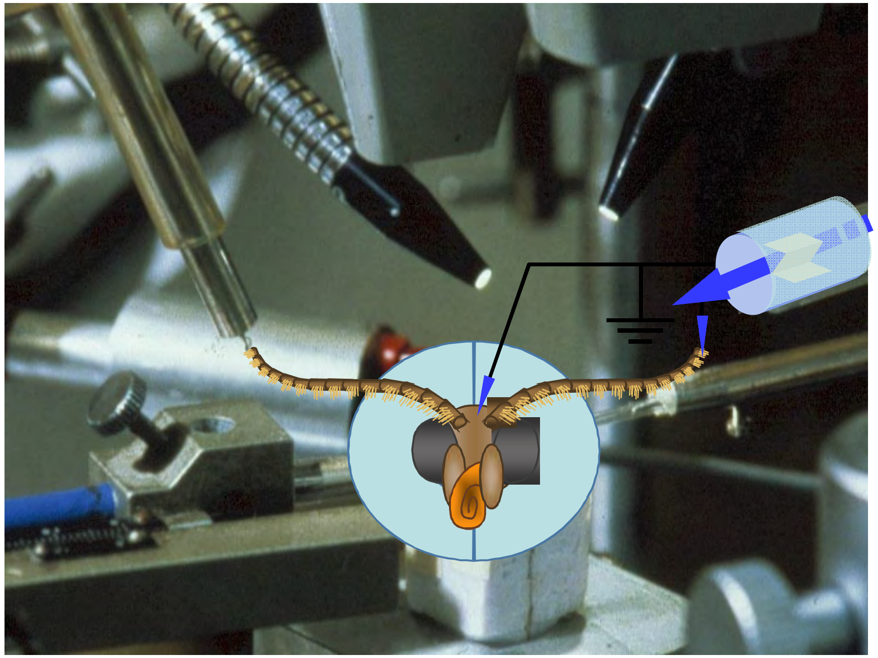
PAM

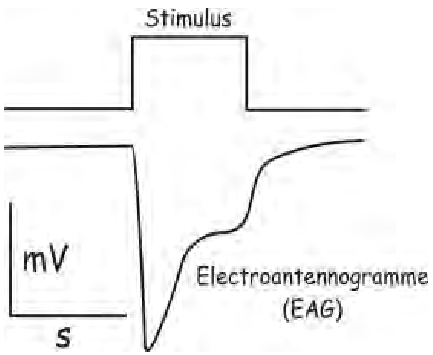
gRNA

13 different mutations observed,
most with interupt coding sequence

Koutroumpa et al 2016 Sci Reports

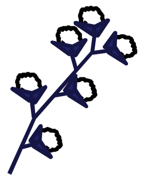
G2 Phenotyping
electroantennography (EAG)



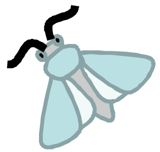


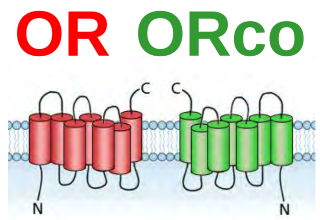
Odorants tested:

E-ocimene
Z3-hexenyl-Ac
E2-hexenol
benzyl OH
PAA

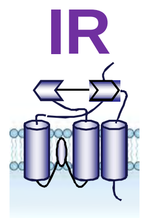


Z9, E12-14:Ac
Z9, E11-14:Ac

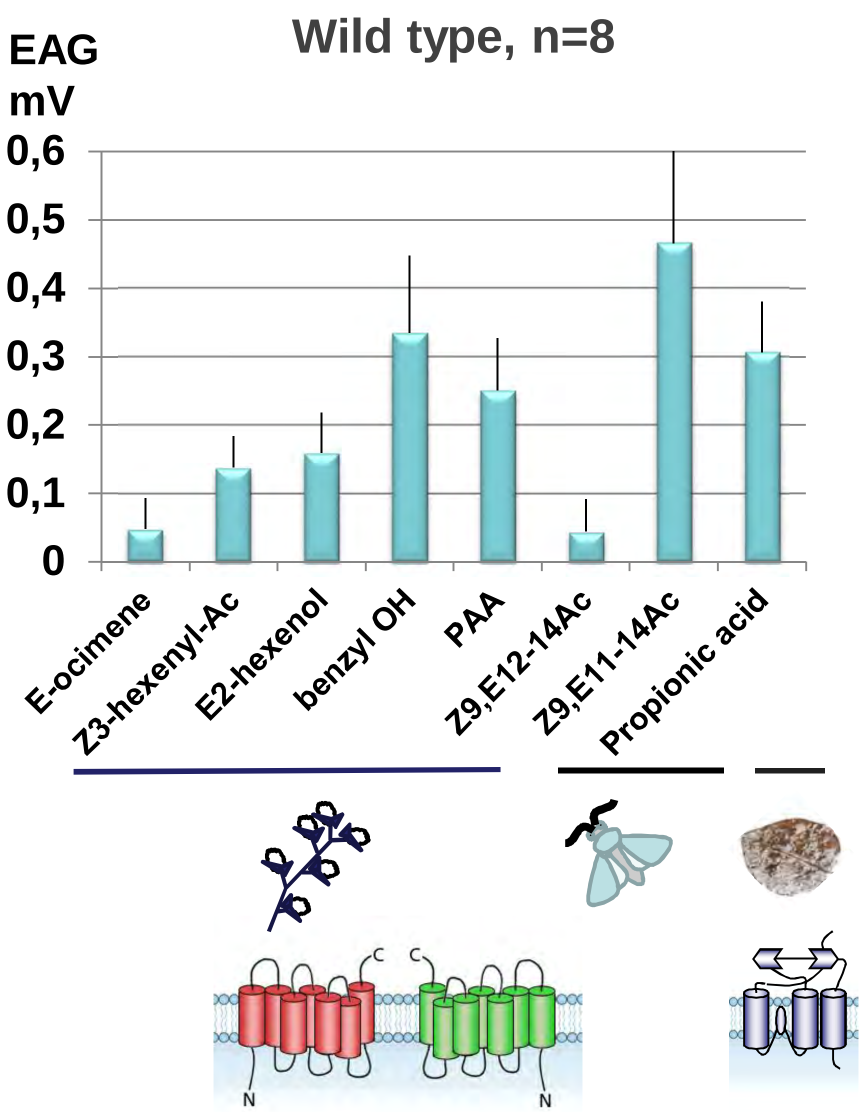


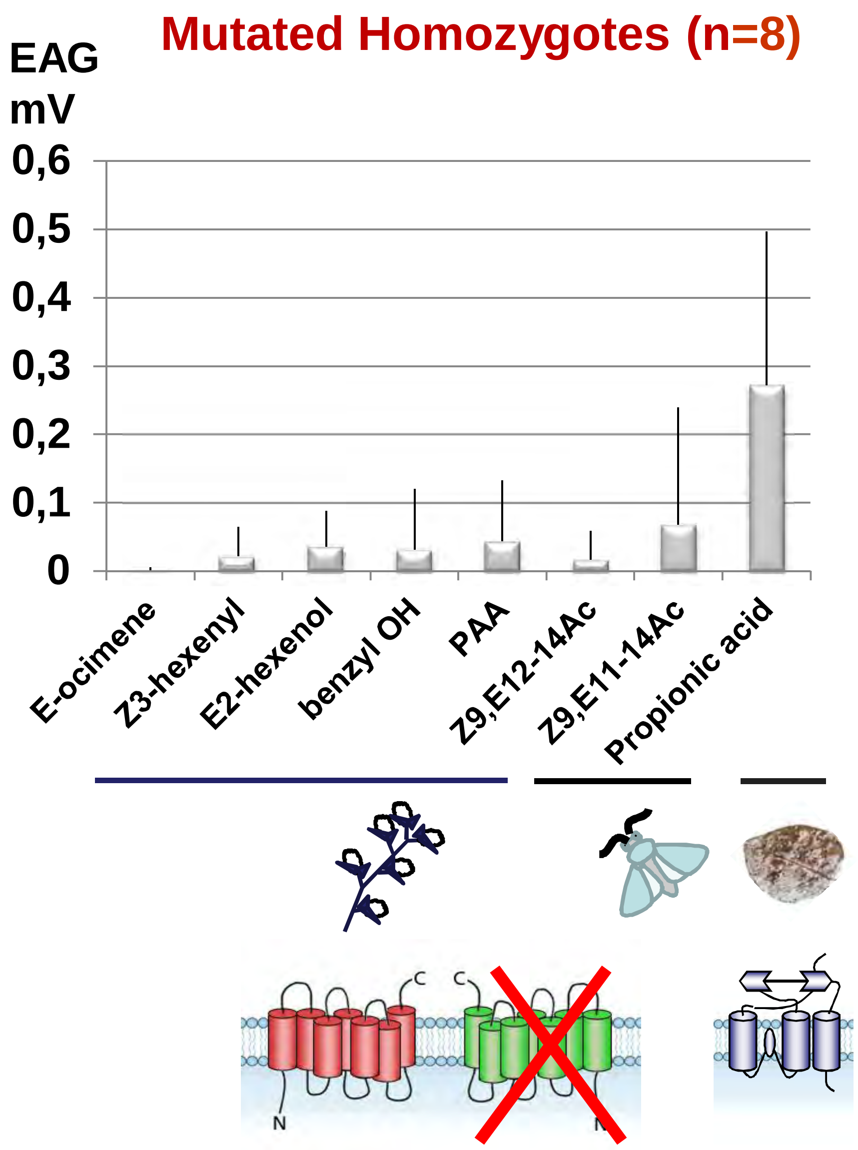


Propionic acid



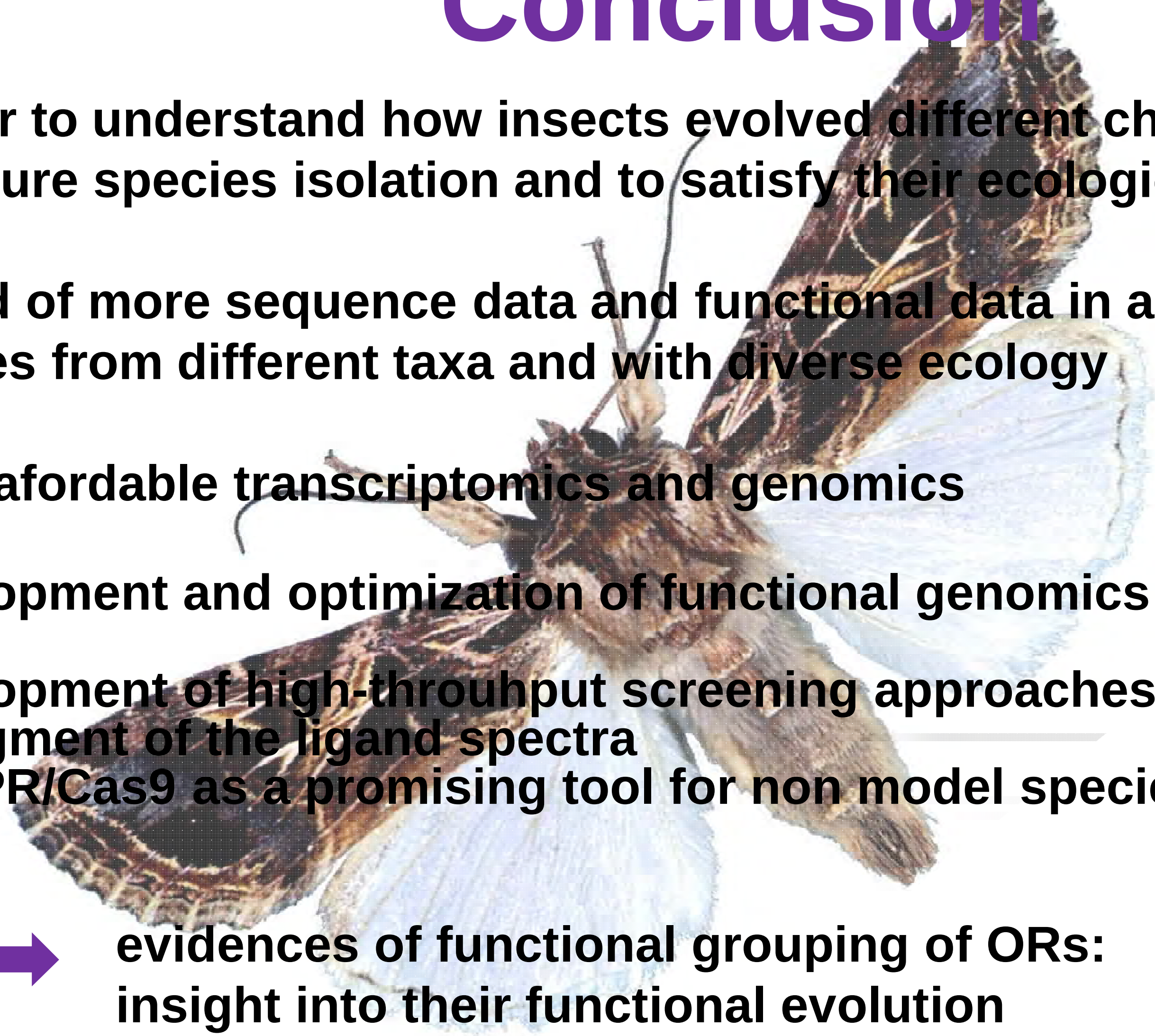
Phenotyping G2





Koutroumpa et al 2016 Sci Reports

Conclusion



still far to understand how insects evolved different chemoreceptors to ensure species isolation and to satisfy their ecological needs

a need of more sequence data and functional data in a diversity of species from different taxa and with diverse ecology

NGS: afordable transcriptomics and genomics

Development and optimization of functional genomics:

Development of high-throuhput screening approaches
Enlargment of the ligand spectra
CRISPR/Cas9 as a promising tool for non model species

ANR

DEMETER
2017-2021

→ evidences of functional grouping of ORs:
insight into their functional evolution

→ identified targets in pest control

Neglegted IRs and GRs!

iEES Paris

Nicolas Montagné

Thomas Chertemp

Arthur de Fouchier, PhD

Erwan Poivet, PhD

Aurore Gallot, post-doc

Olivier Mirabeau, post-doc

Fotini Koutroumpa, post-doc

Marie-Christine François

Christelle Monsempes

BIPAA Bioinformatic Platform Rennes:

Fabrice Legeai, Anthony Bretaudeau

DGIMI Montpellier: Emmanuelle dôAlençon & the FAW genome consortium

William Walker, Bill Hansson,’ Mattias Larsson

Jean-Paul Concordet,Anne De Cian
Corrine Royer