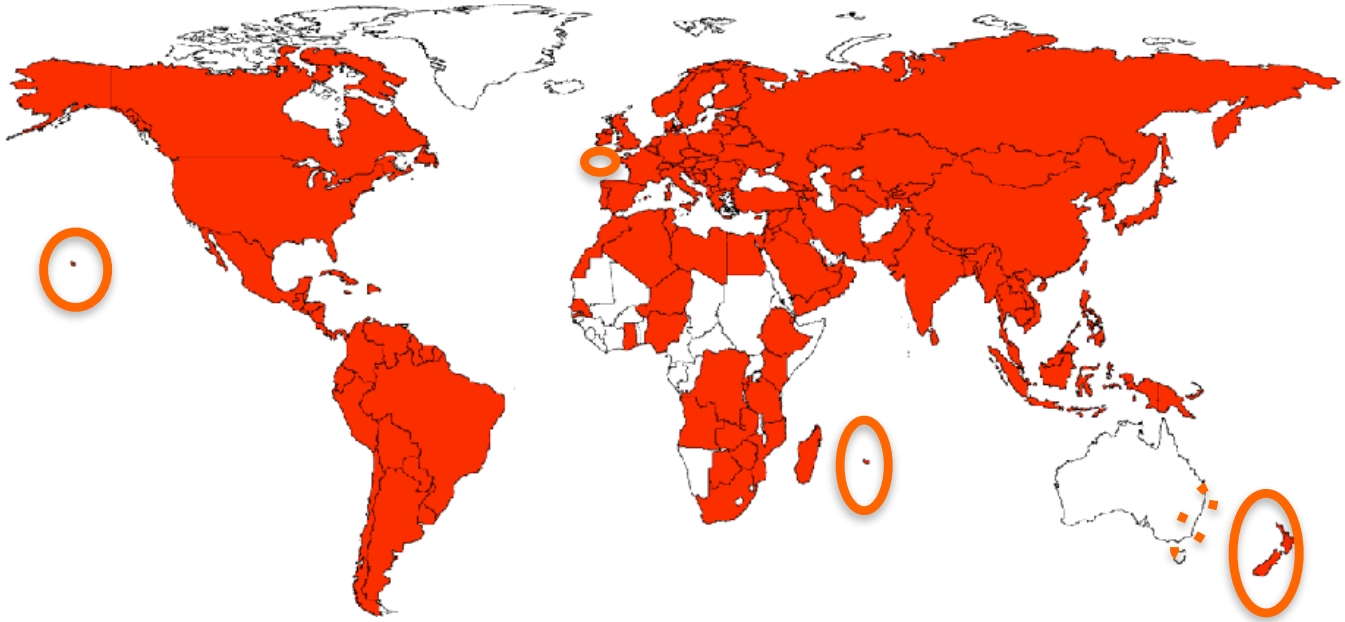
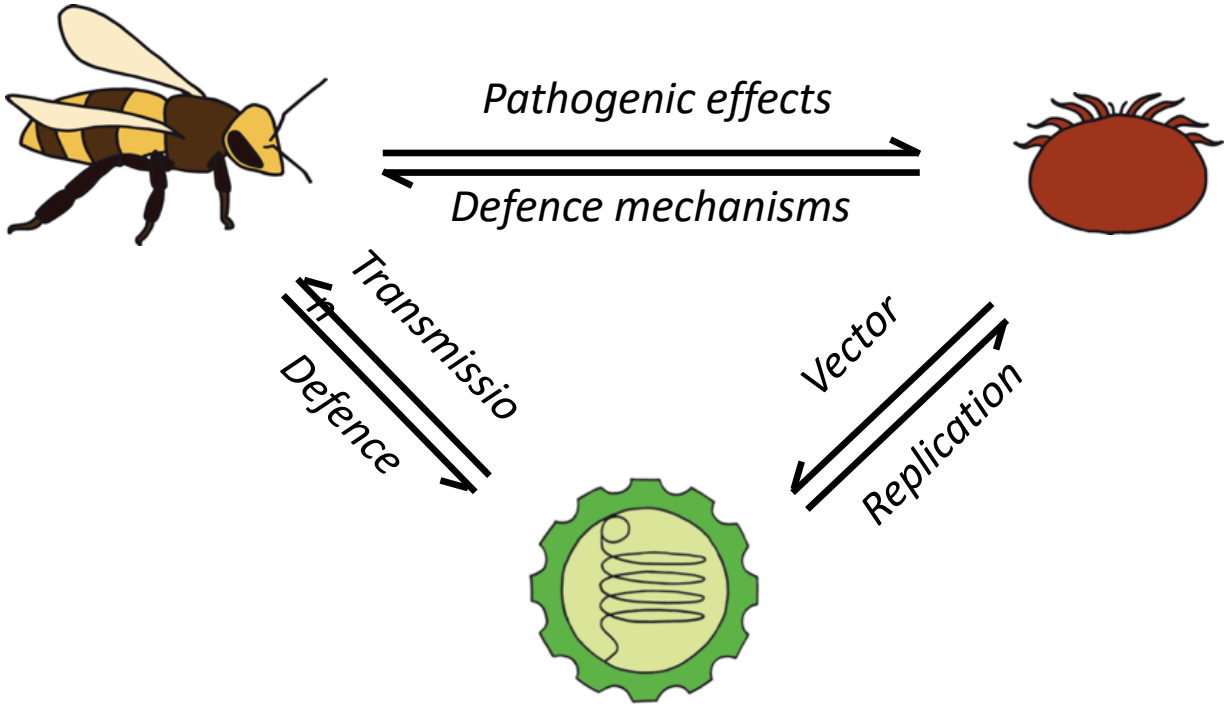
Honey bees surviving *Varroa destructor* infestations: lessons we can take

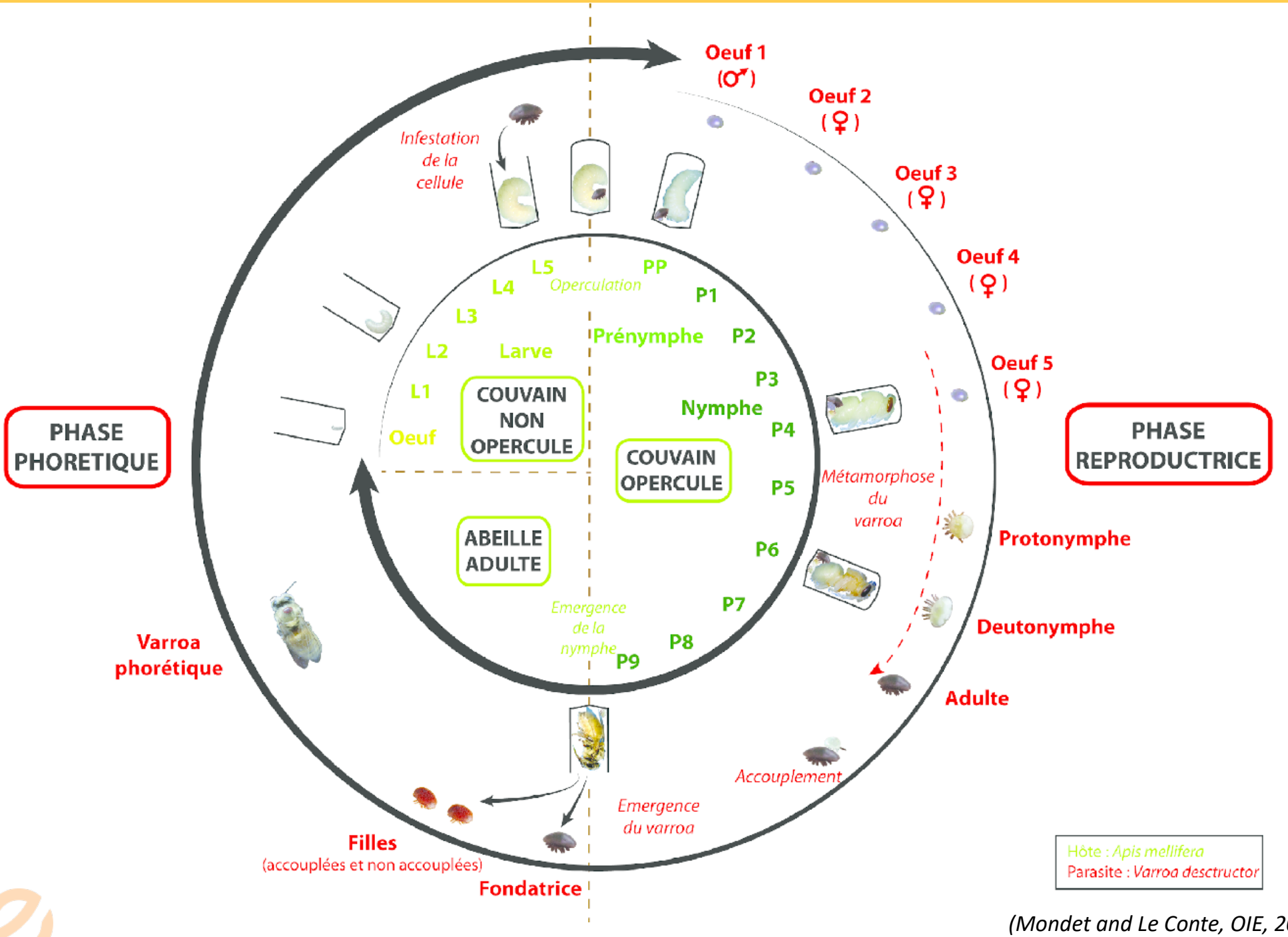
Fanny Mondet & Yves Le Conte

Varroa: biotic threat no.1 for honey bees



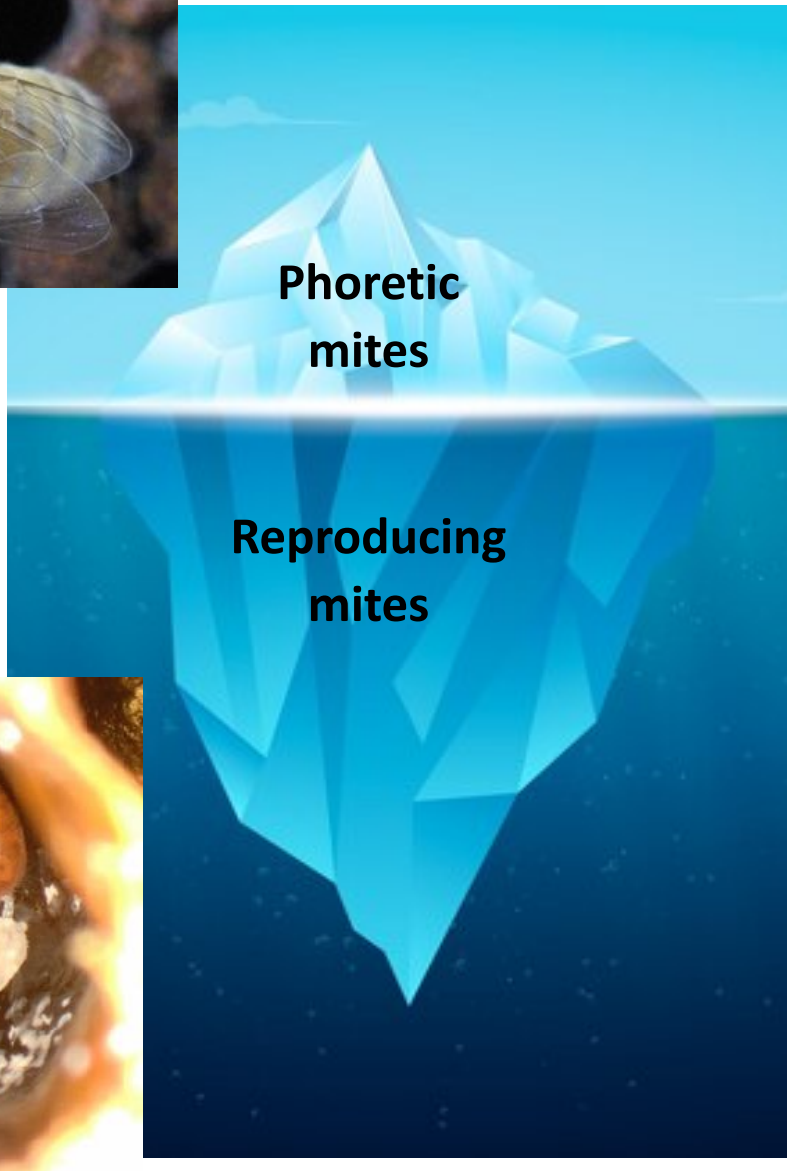


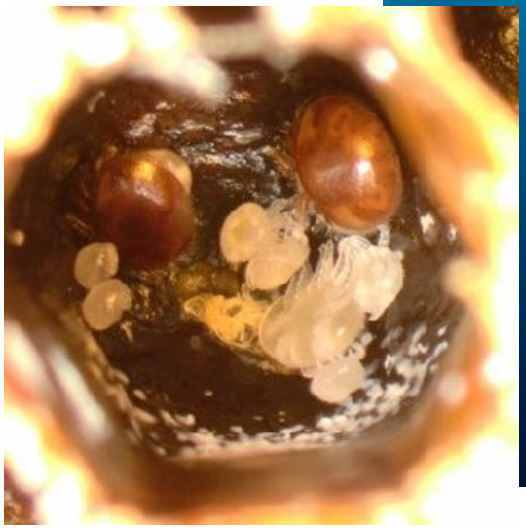
Cycle de reproduction du varroa (1/2)

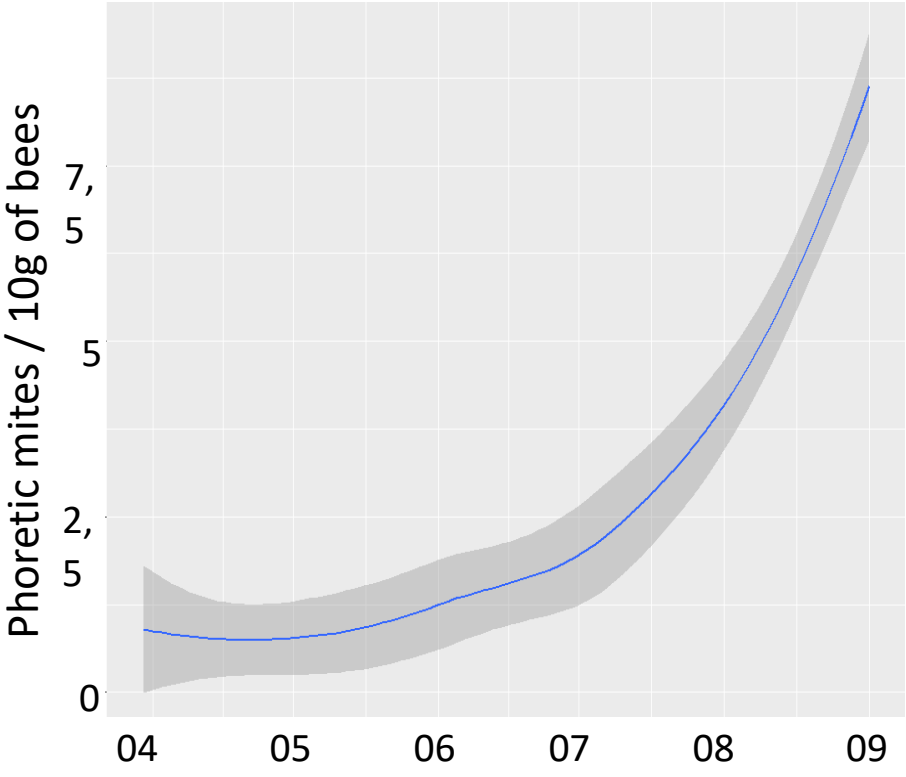


(Mondet and Le Conte, OIE, 2014)

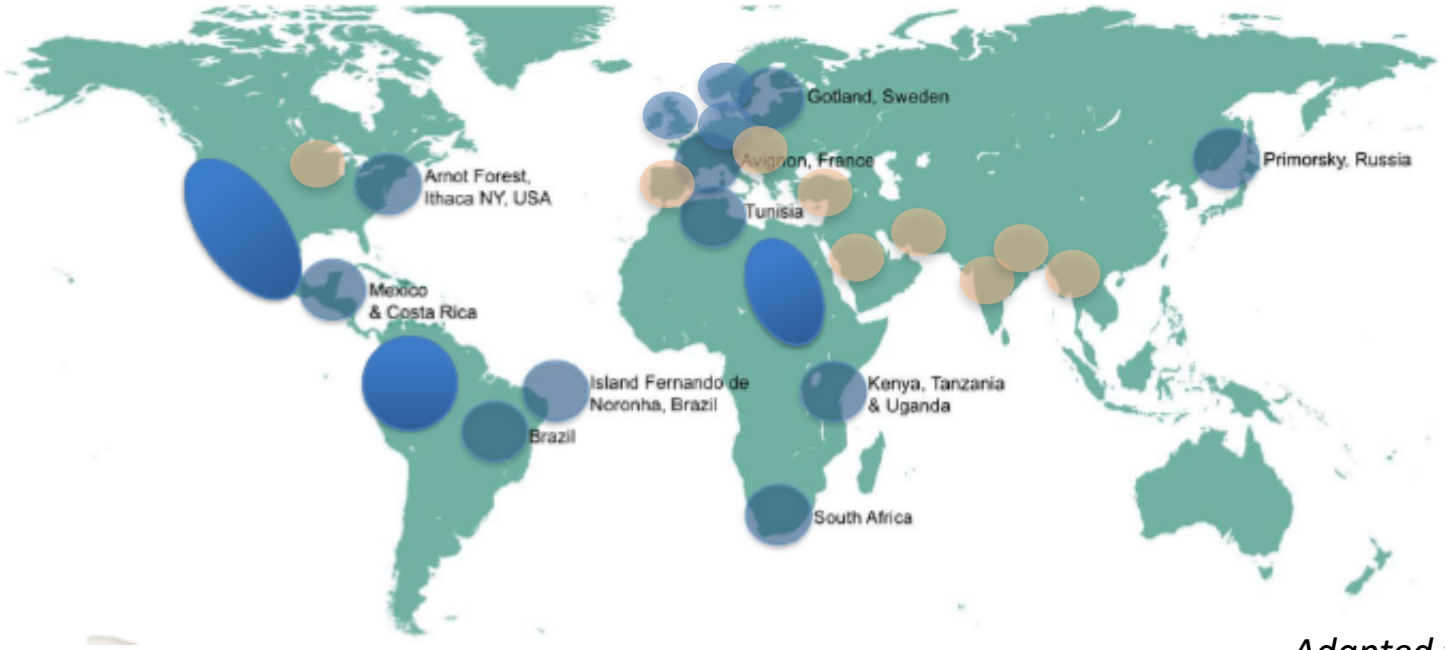
La face cachée de l'iceberg…



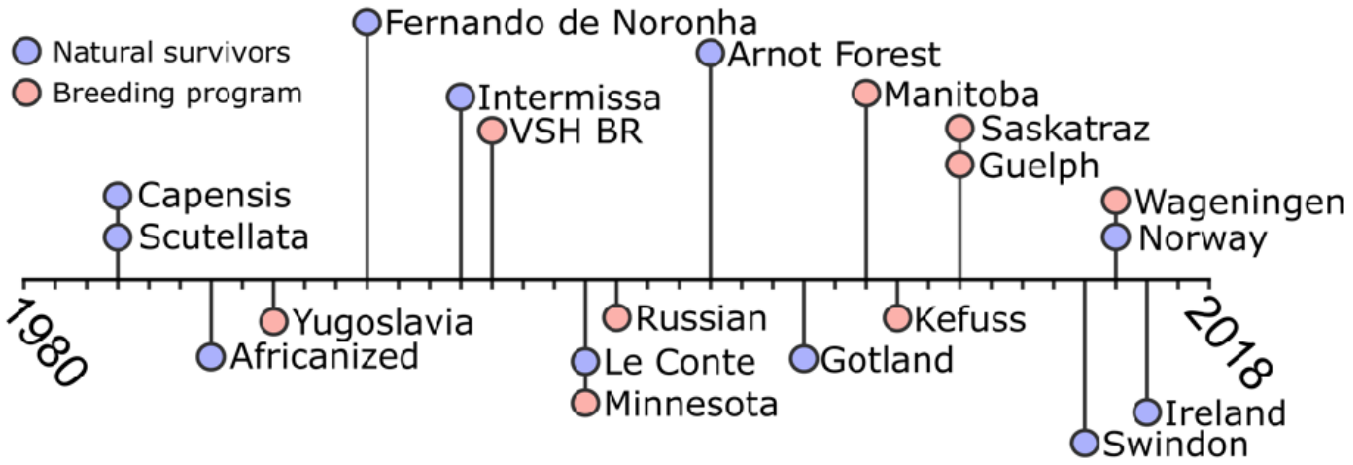




Varroa surviving honey bee populations



Adapted from Locke et al. 2015
Moro et al. 2021



Mondet et al. 2020

Resistance/tolerance mechanisms

Tolerance

Host reduces impairment caused by the parasite when the infestation is at a level that typically causes damage

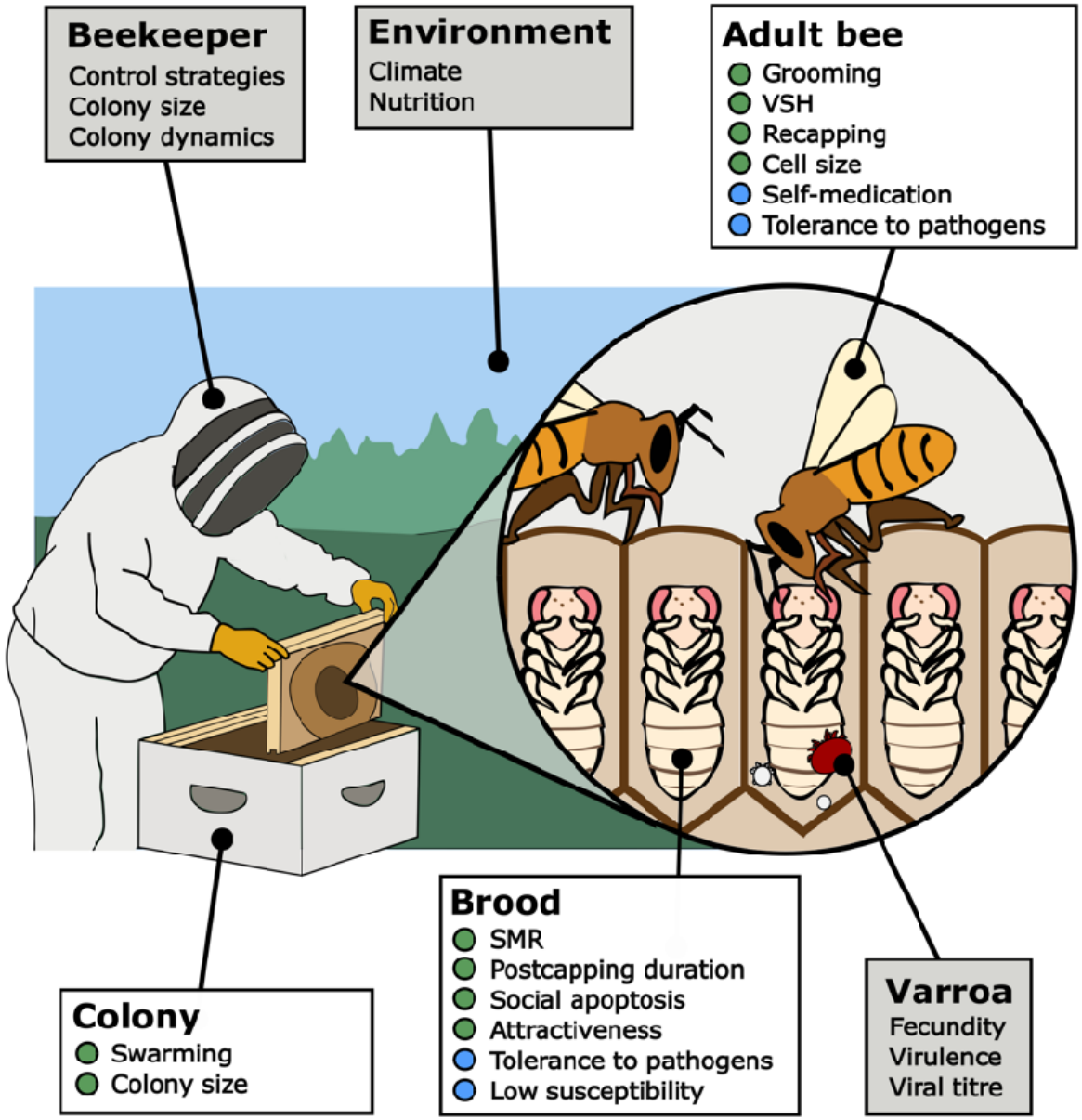
Resistance

Host reduces parasite fitness (reproductive success) to keep the population below a damaging threshold

High MNR, low fecundity

Low mite population growth

Low infestation

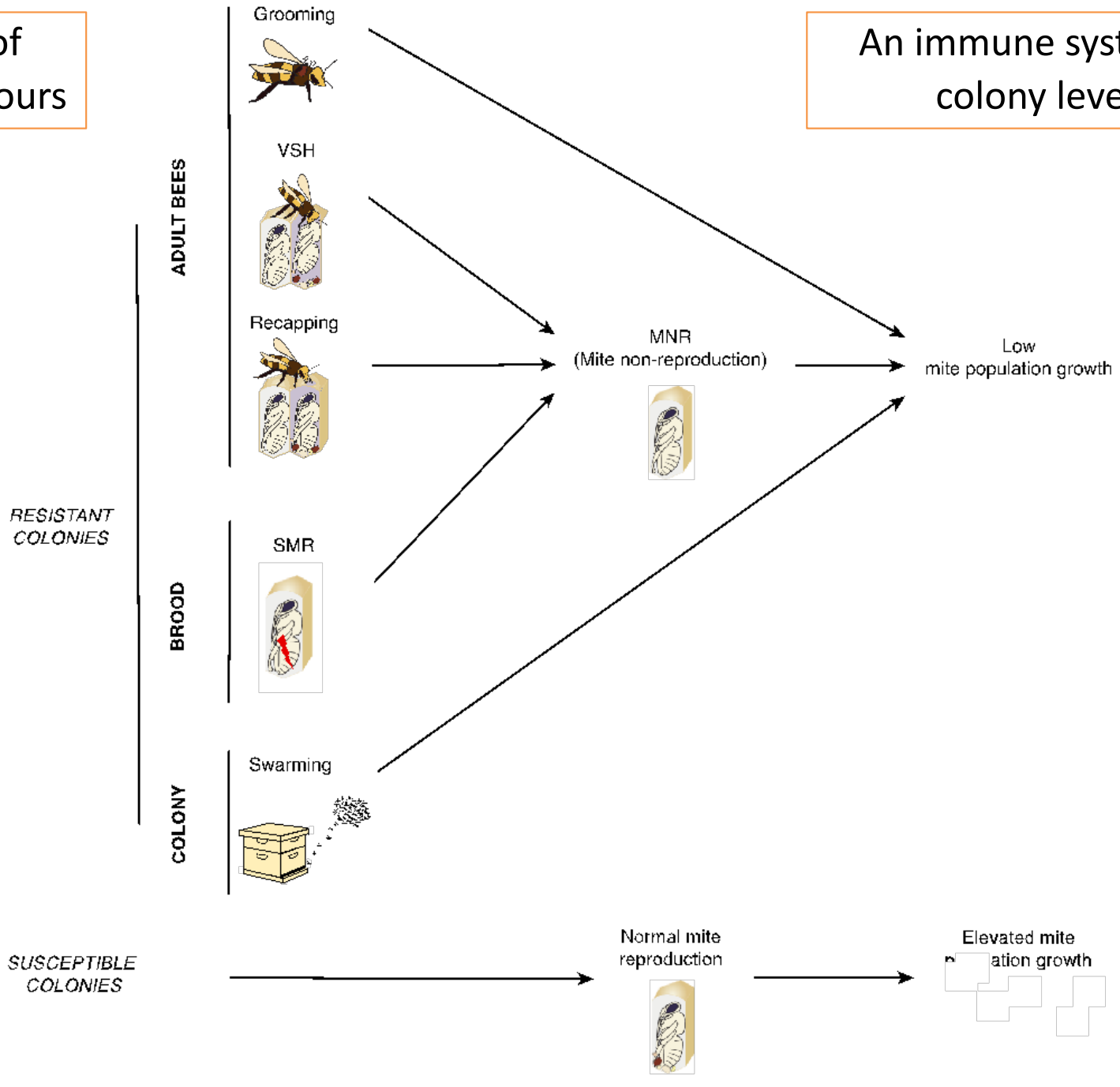


Mondet et al., 2020

Resistance and behaviours

Importance of defence behaviours

An immune system at colony level!



Mechanisms of resistance

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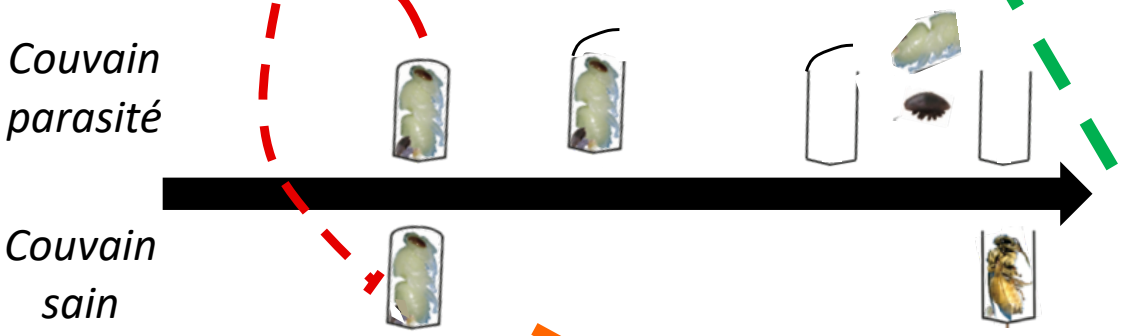
Action des abeilles adultes

VSH (Varroa Sensitive Hygiene)

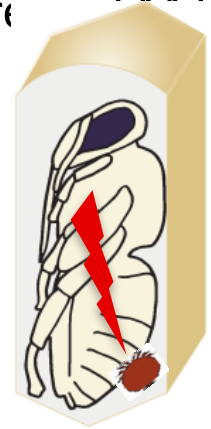
Détection → Désoperculation → Nettoyage



Action du couvain

Inhibition de la reproduction

SMR (Suppre[illegible]e Reproduction



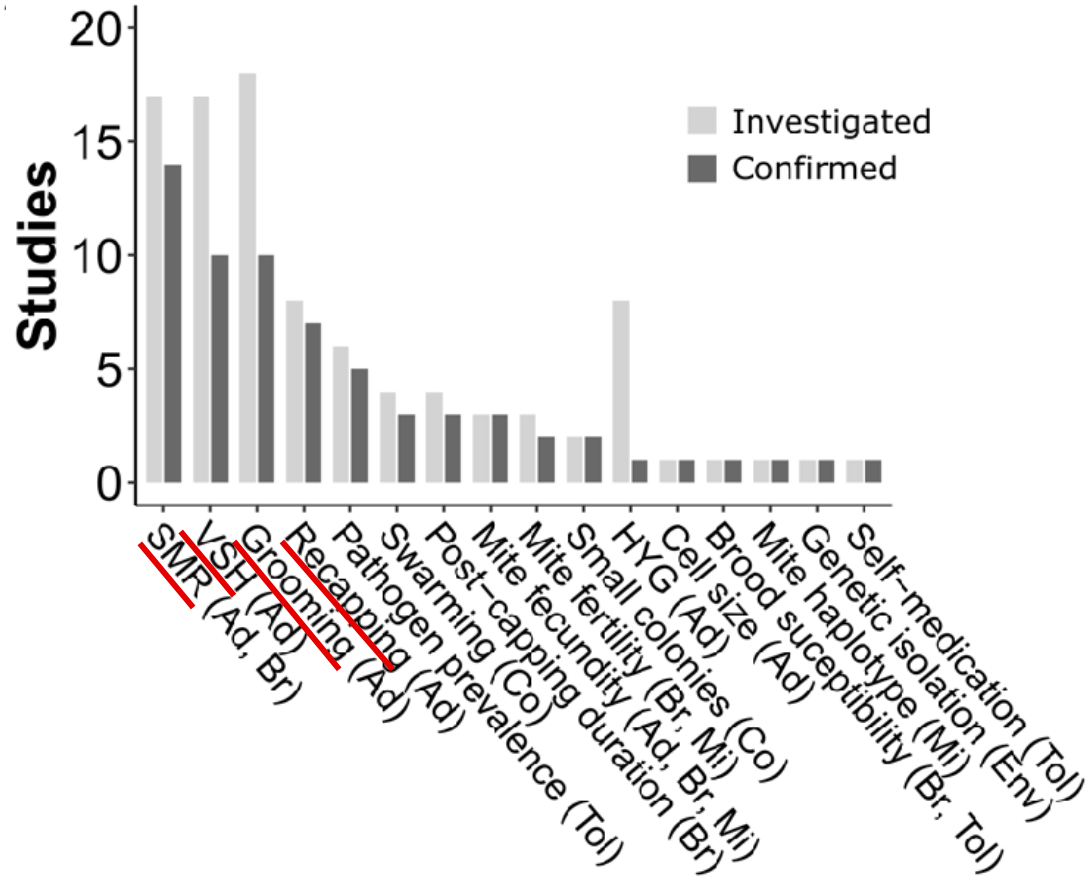
Echec de reproduction des femelles varroa

MNR (Mite Non Reproduction) - SMR

Physiologie varroa

Environment (beekeeper, viruses)

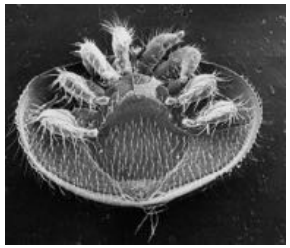
Resistance/tolerance mechanisms

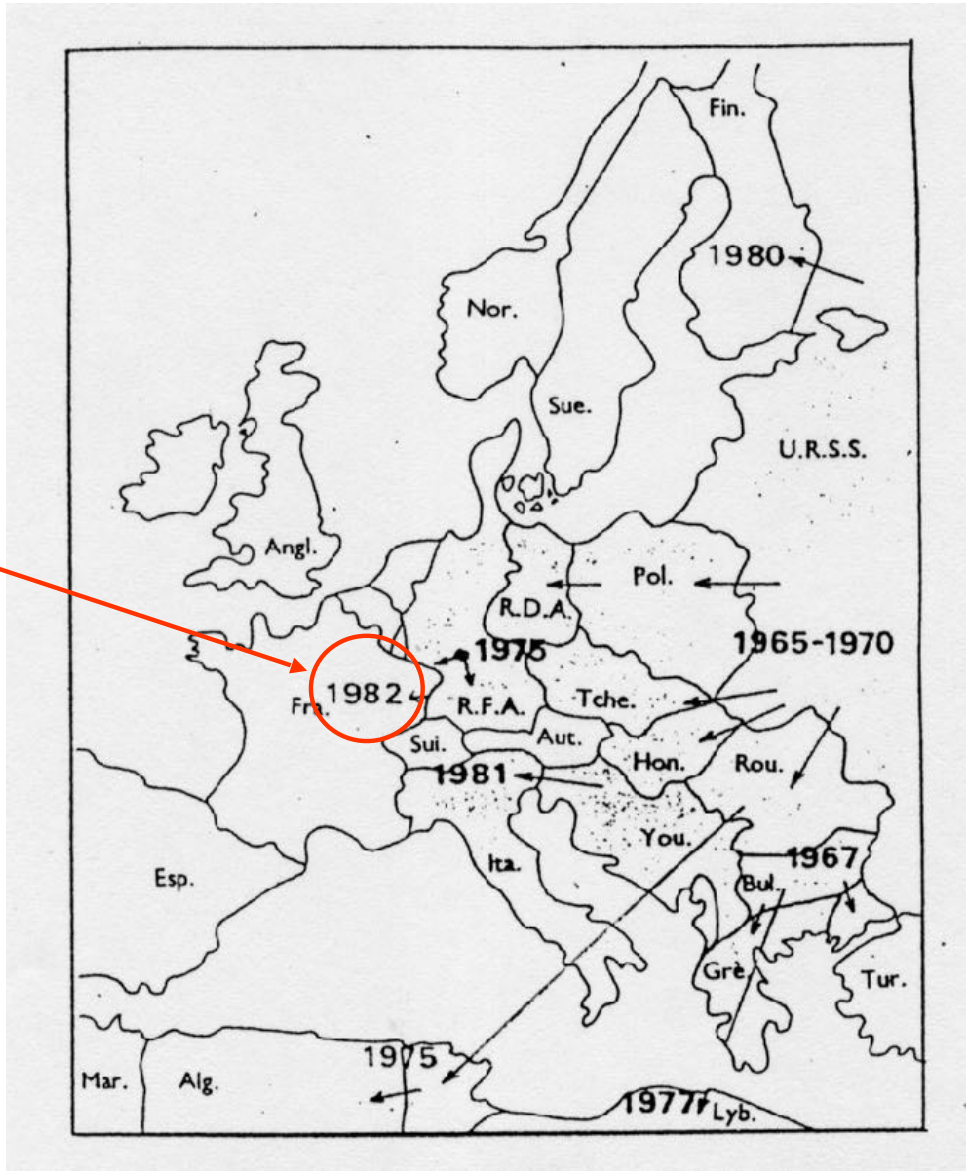


Mondet et al., 2020

My story !

Historic :Apparition of *Varroa* in France in 1982





Untreated colonies die after 1 to 2 years of infestation !!!

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1995

Come back of feral colonies

Untreated colonies

more or less abandoned

seem to survive !

I- Validation of the survival of the honey bee colonies

Investigation and survey to the beekeepers => set up of a different apiaries with 70 candidate colonies :

- Apiaries in Avignon in la Sarthe, In Orne,

I- Validation of the survival of the honey bee colonies

Queen paint marked

2 monthly visits of the colonies from early spring to early winter

Check for diseases => no pbs

No other manipulations

I- Validation of the survival of the honey bee colonies

Colonies can survive more than 2 years !

7.63 ± 0.3 years, maxi: 15 years

Since 2007: still surviving bee colonies

Le Conte Y, de Vaublanc G, Crauser D, Jeanne F, Rousselle J-C, Bécard J-M. 2007. Apidologie 38:1–7.

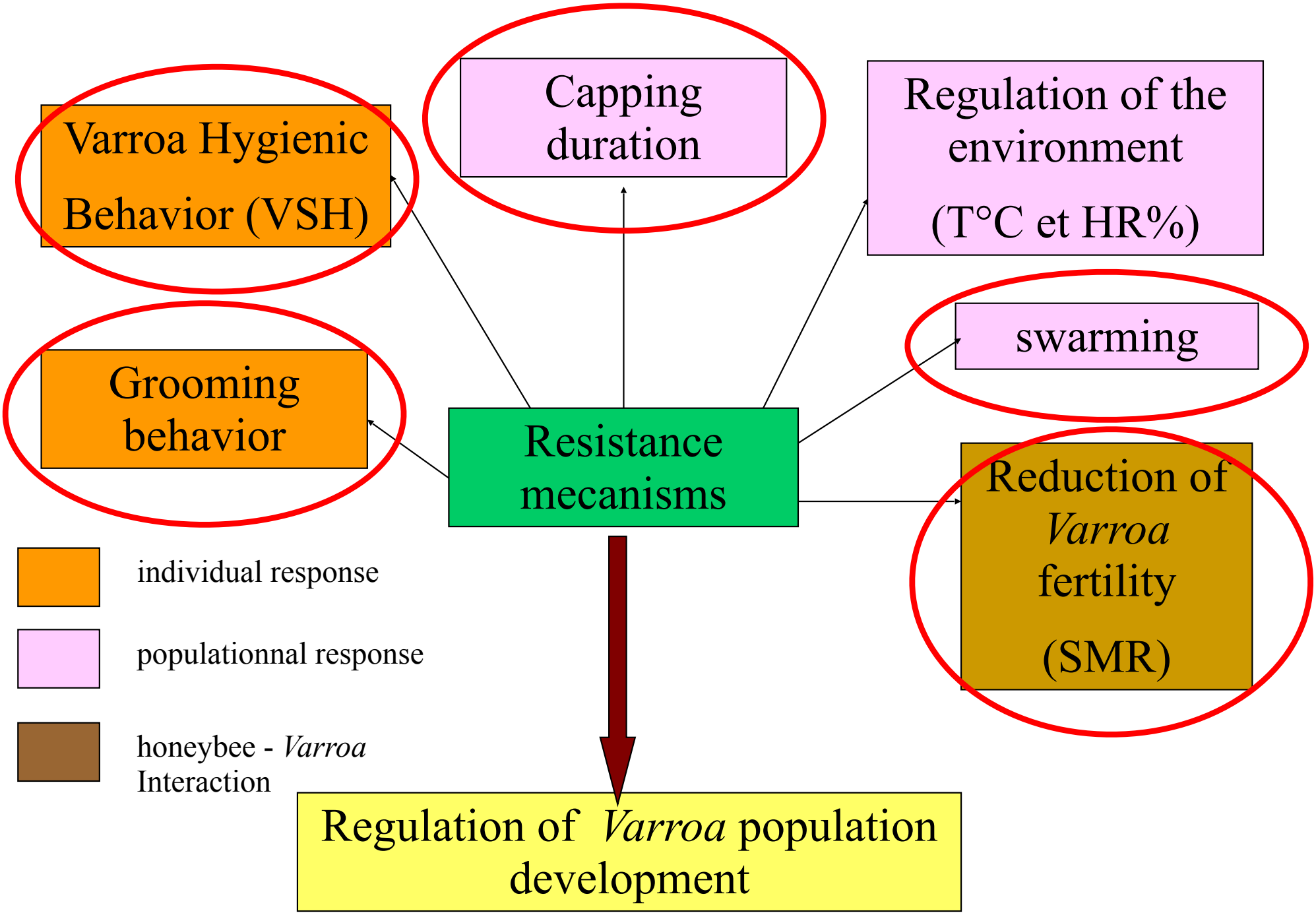
Survival of the honey bee colonies

Interest of those bees ?

Research:

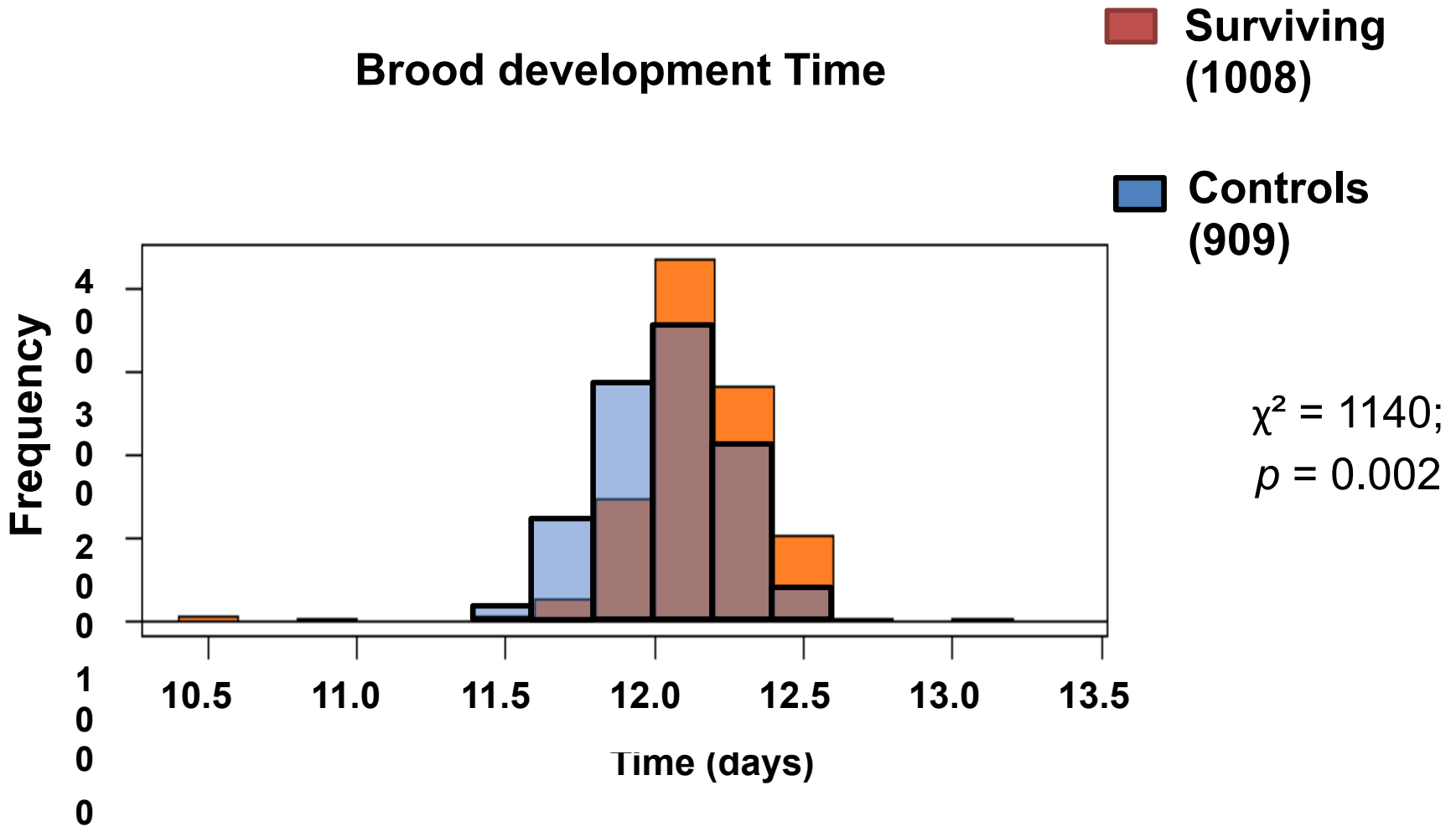
- Great subject to play with!!!

Resistance / Tolerance of the honey bee?



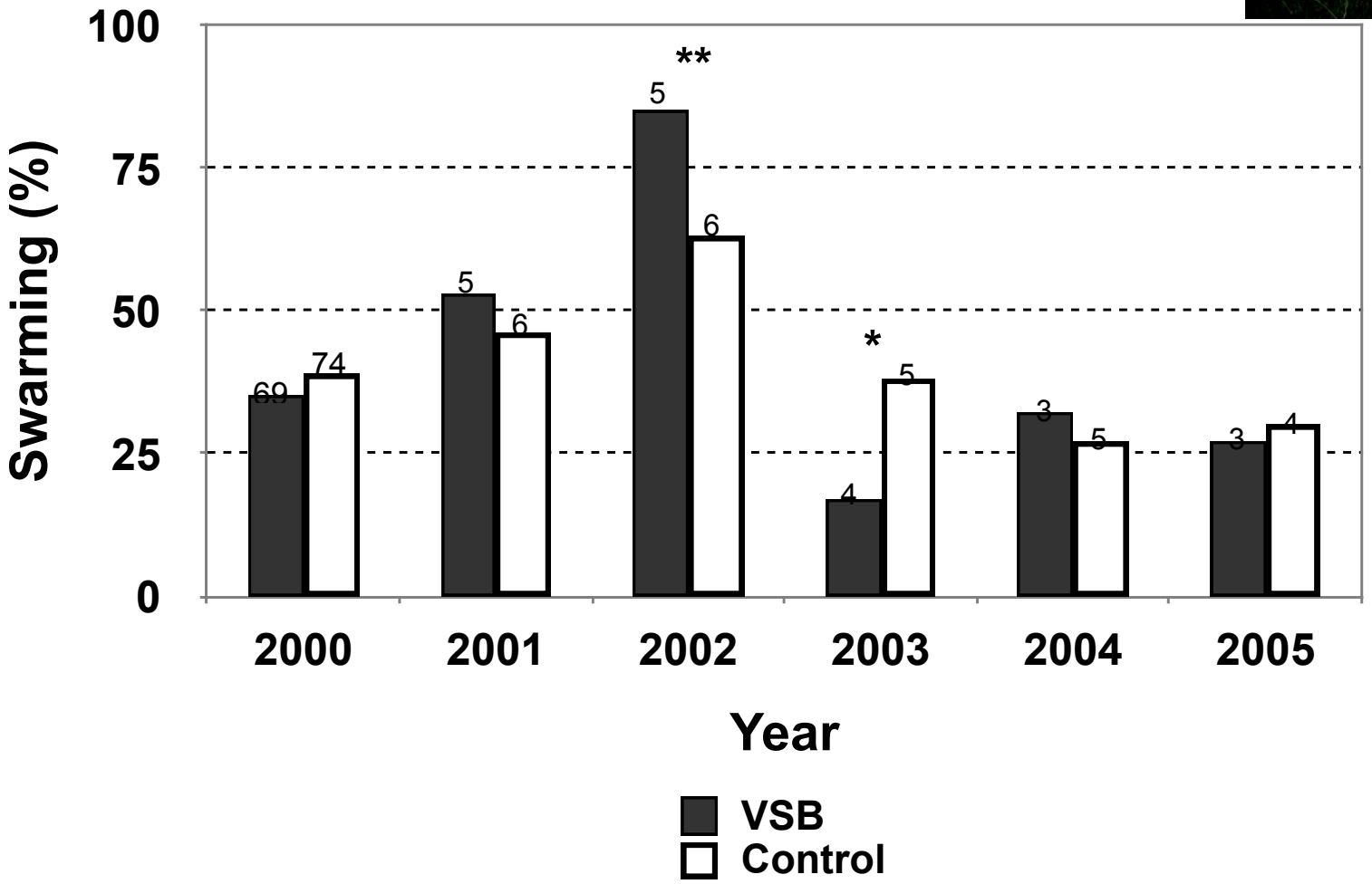
Rosenkranz P. (1999) Apidologie 30, 159-172.

Post capping



$\chi^2 = 1140$;
$p = 0.002$

Swarming



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Resistance of the bees to the mite:

Hypothesis tested : **Grooming behavior**

Ability of the bees to recognize
and destroy the varroa mite

Different behavioral test =>

Differences in detection of the mite between surviving and control colonies

MARTIN C., SALVY, M., PROVOST E., BAGNÈRES A.G., ROUX M., CRAUSER D., CLÉMENT J.L., LE CONTE Y., 2002 –***Physiological Entomology***. 27: 175-188.

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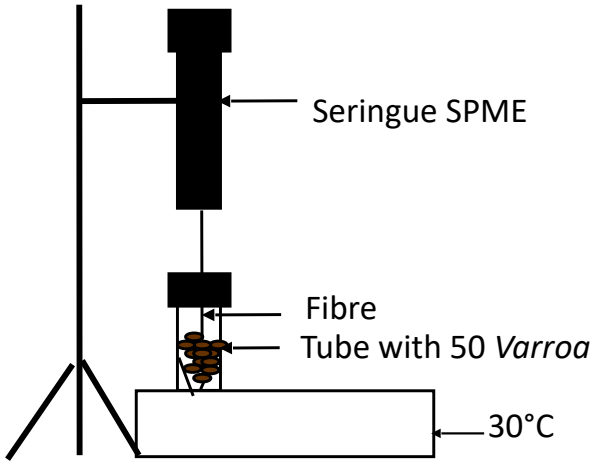
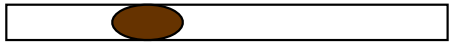
Olfaction in varroa recognition by the bees ?

- Solid Phase Micro-Extraction (SPME)



- Solid Injection (IS)



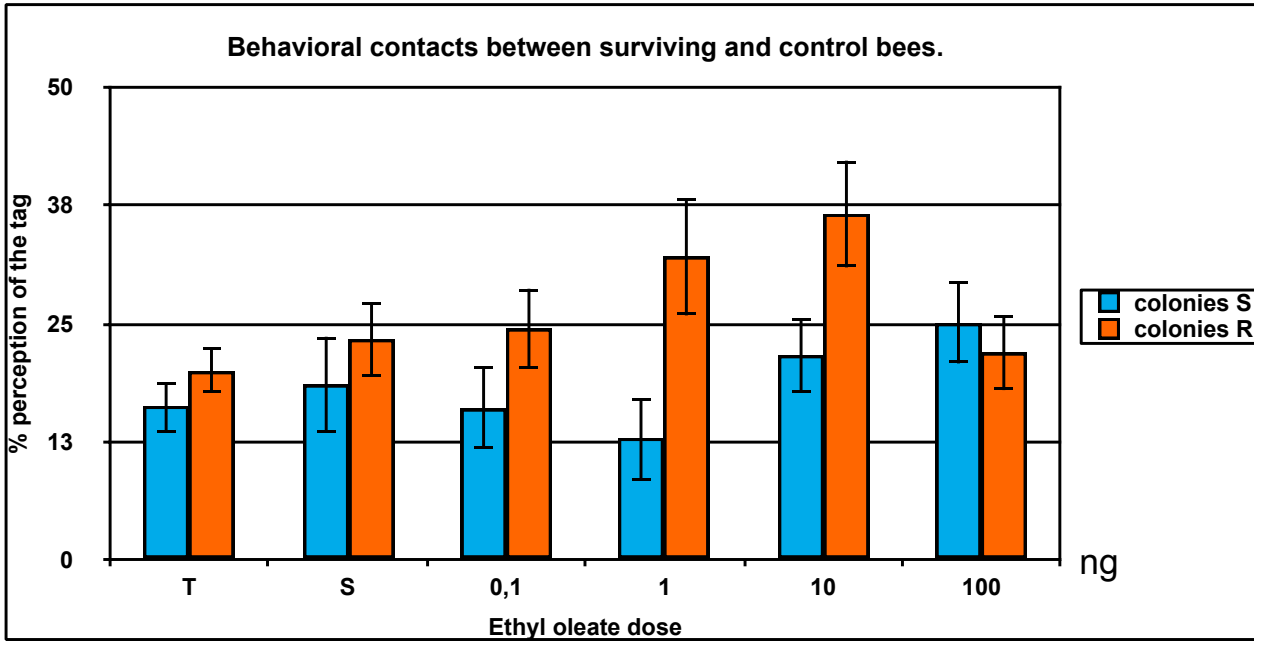
- Capillary insert in the injecteur of the GC

Identified Substances with SPME and IS

- Micro-Extraction
  - Cuticular hydrocarbons
  - 3 Acids (palmitic, oleic, stearic)
  - 1 alcool
- Solid Injection
  - Cuticular hydrocarbons
  - 8 acids
  - 3 esters (palmitate, oléate, stéarate d'éthyle)

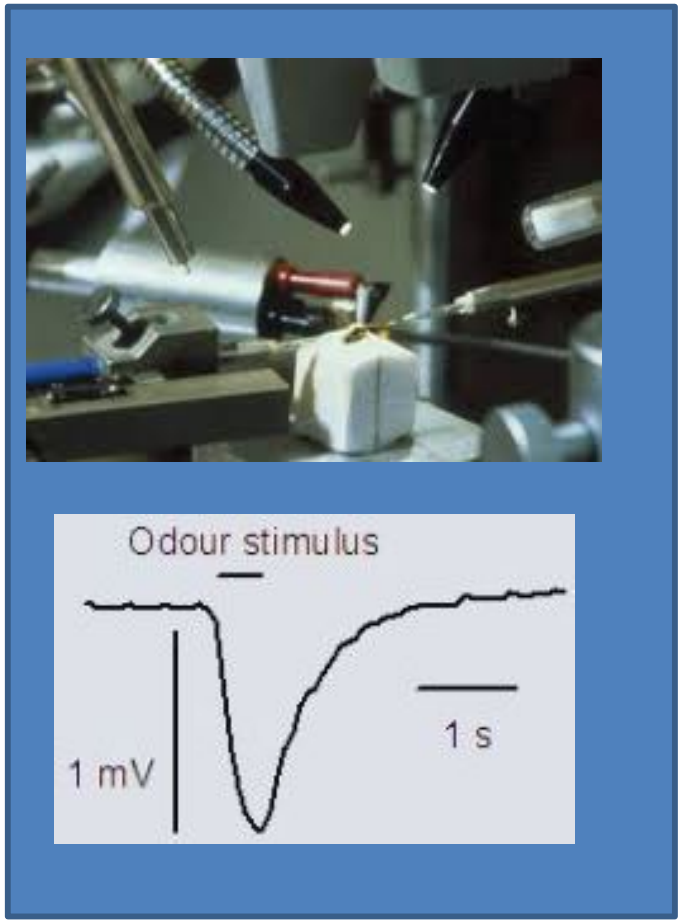
Martin C., Provost E., Roux M., Bruchou C., Crauser D., Clement J.L., Le Conte Y. ***Physiological Entomology***. *2001. 26: 4, 362-370.*

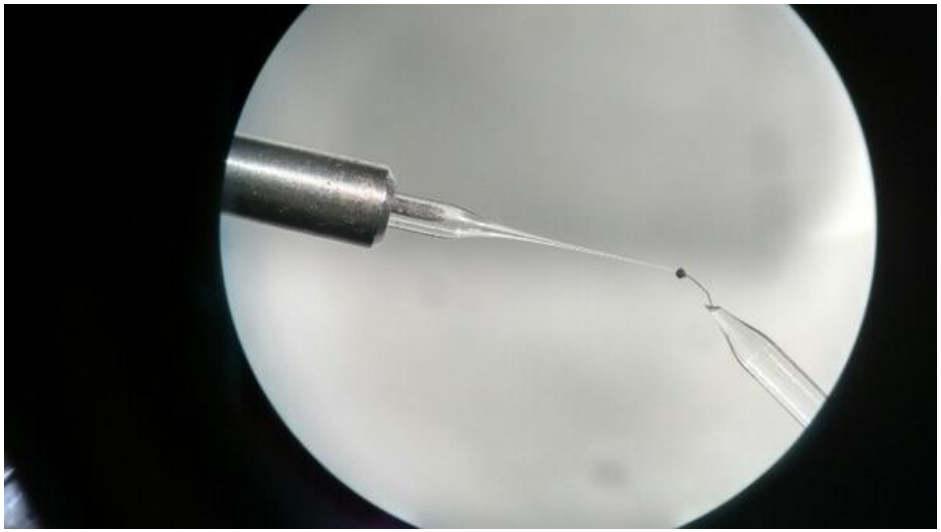
Behavioral effects on the bees



Three of the compounds trigger a behavioral response

Electroantennography (EAG)





Surviving bees are responding more

than control bees

Confirm the better capacity of the surviving bees to recognize the mite

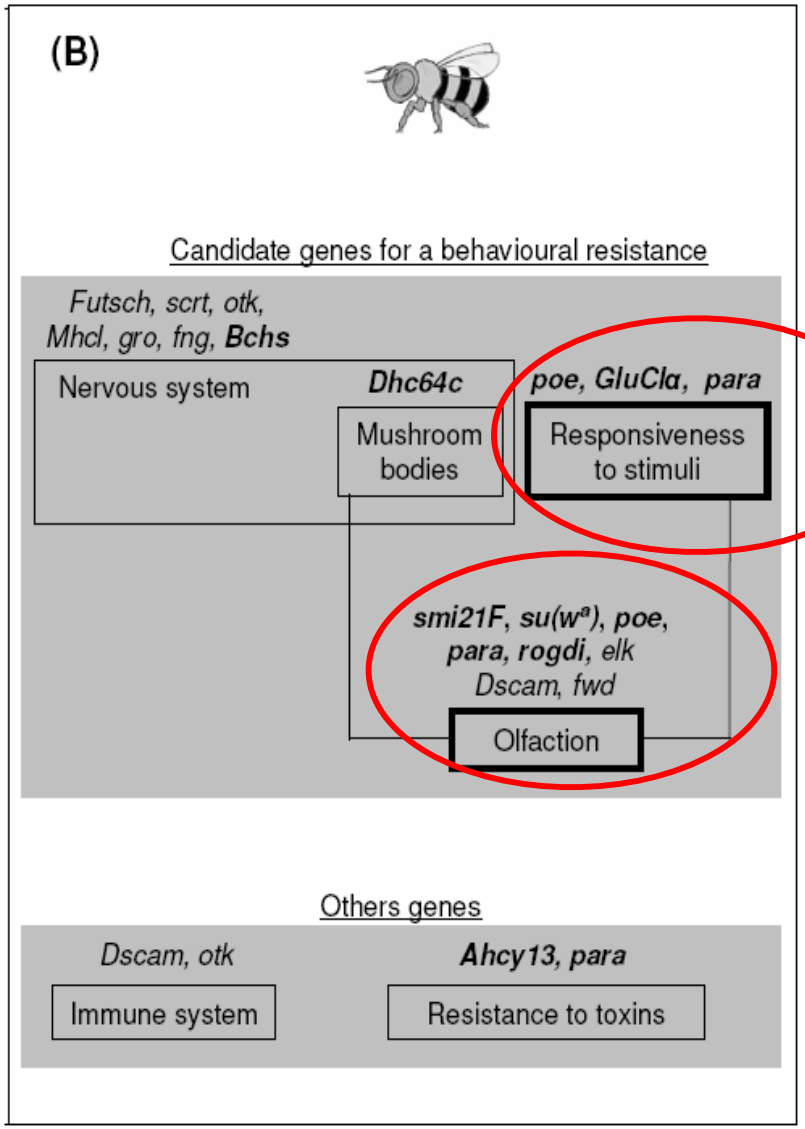
Martin C., Provost E., Roux M., Bruchou C., Crauser D., Clement J.L., Le Conte Y. ***Physiological Entomology***. *2001. 26: 4, 362-370.*

Honey bee *Varroa* tolerance :

Gene expression analysis: transcriptomic

Pangenomic approach
method for the identification of candidat genes

INRAE



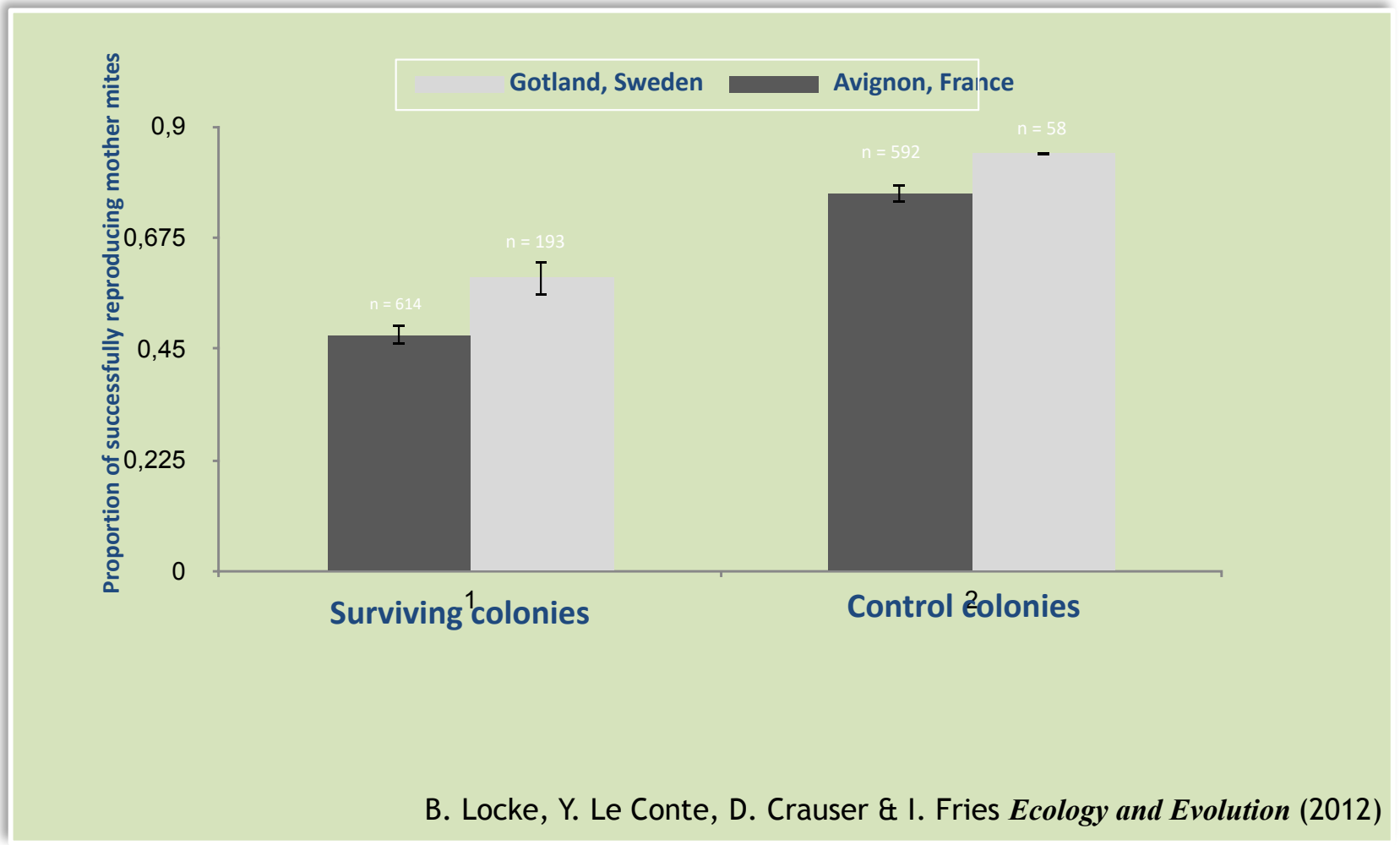
Hypothetical pathways of honey bee responses to the bee tolerant genotype.

Gene names in bold are up-regulated.

NAVAJAS M., MIGEON A., ALAUX C., MARTIN-MAGNIETTE ML., ROBINSON GE., EVANS JD., CROS-ARTEIL S., CRAUSER D., LE CONTE Y. 2008. ***BMC Genomics* 2008, 9:**301doi:10.1186/1471-2164-9-301.

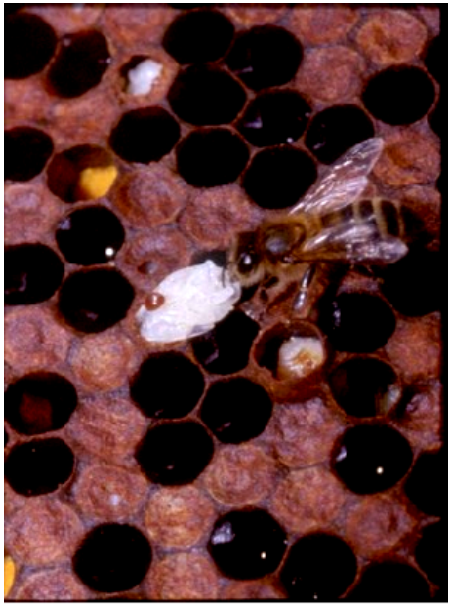
Varroa reproduction in surviving honey bee colonies

Mite non-reproduction
MNR



B. Locke, Y. Le Conte, D. Crauser & I. Fries *Ecology and Evolution* (2012)

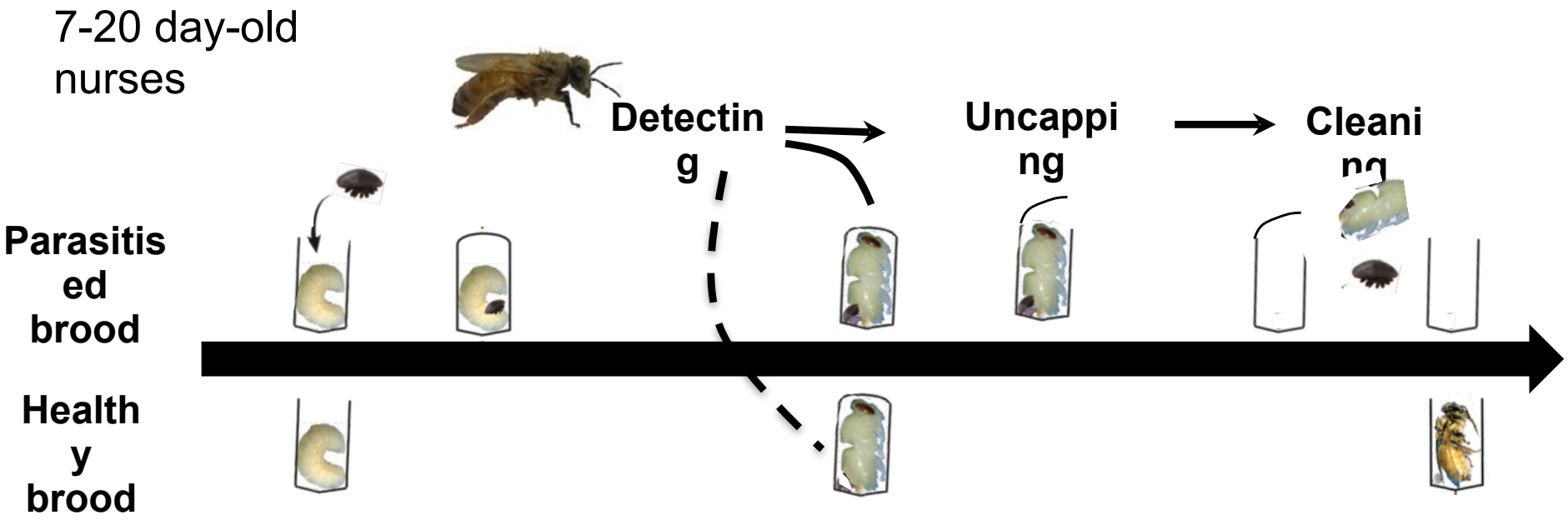
Varroa resistant bees:



VSH : Varroa Sensitive Hygiene Behavior

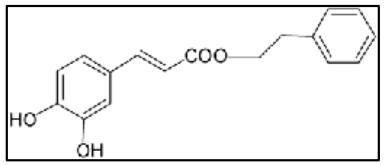
Recapping

They do it!

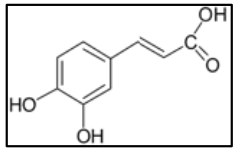


Oddie, M., A Y, Burke, A., Dahle, B., Le Conte, Y., Mondet, F., Locke, B., 2021. Scientific Reports 11, doi:10.1038/s41598-021-88592-y.

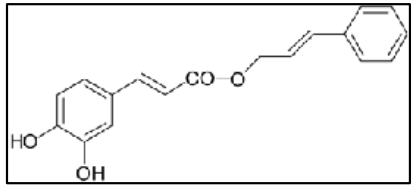
Propolis collection and surviving of the bees



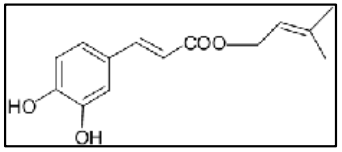
Phenethyl caffeate (CAPE)



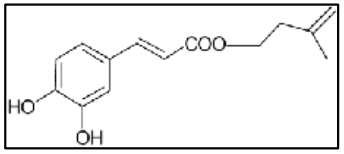
Caffeic acid



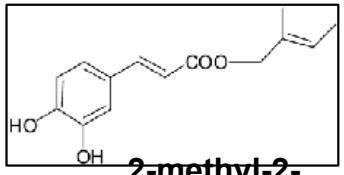
Cinnamyl caffeate



3-methyl-2-butenyl caffeate



3-methyl-3-butenyl caffeate



2-methyl-2-butenyl caffeate

Self-medication ?

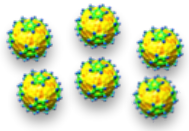
Concentration of caffeic acid and caffetes were higher in propolis collected by surviving colonies

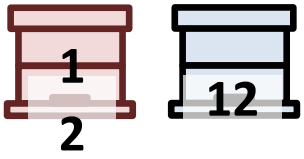
They have pronounced and diverse biological properties

POPOVA, M., M. REYES, **Y**. LE CONTE, AND V. BANKOVA (2014) "Propolis Chemical Composition and Honeybee Resistance against Varroa Destructor." ***Natural Product Research***: 1-7.

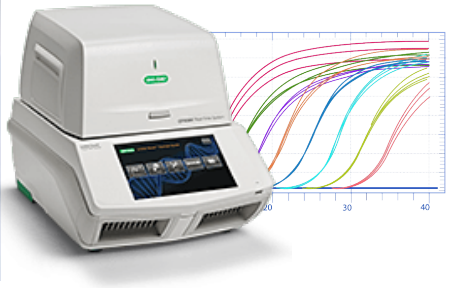
INRAE

2017





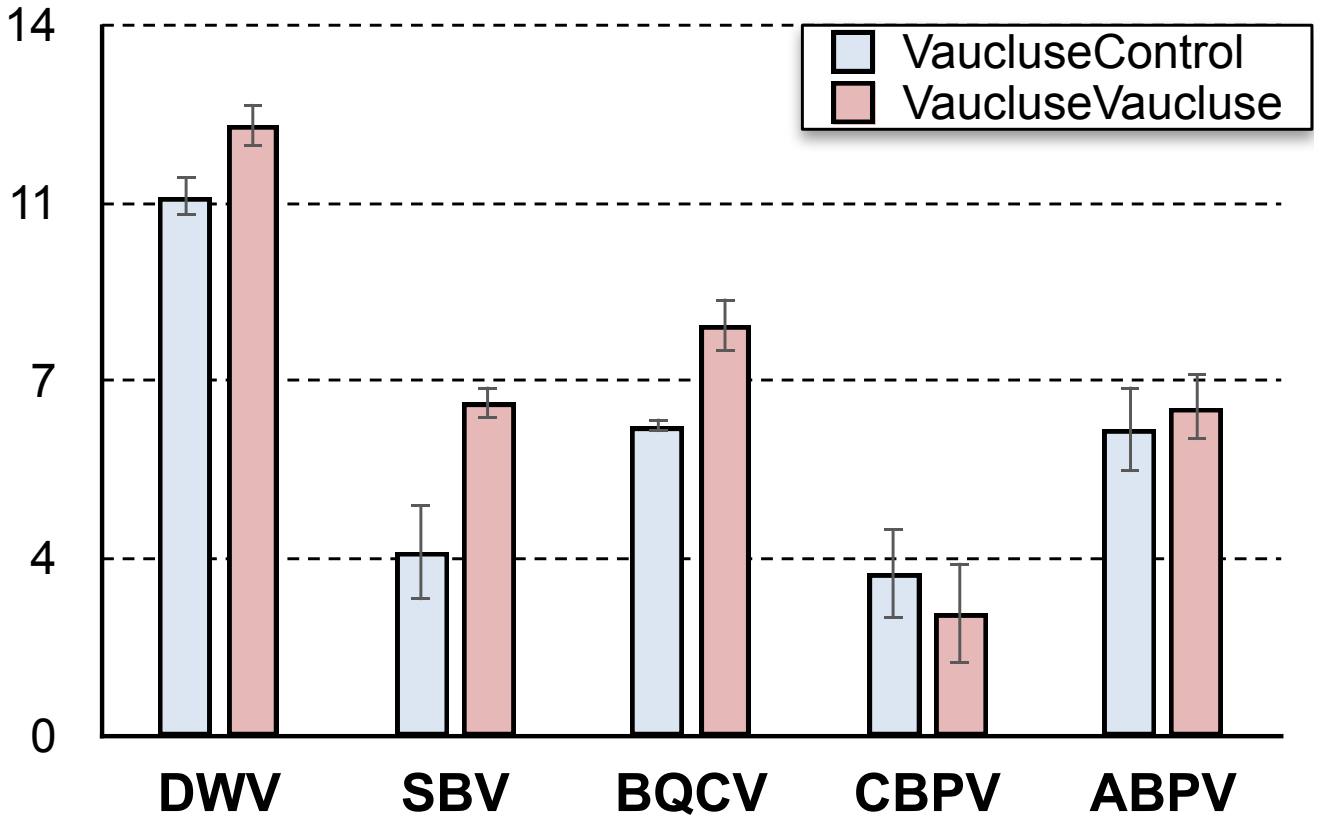
40 bees per colony



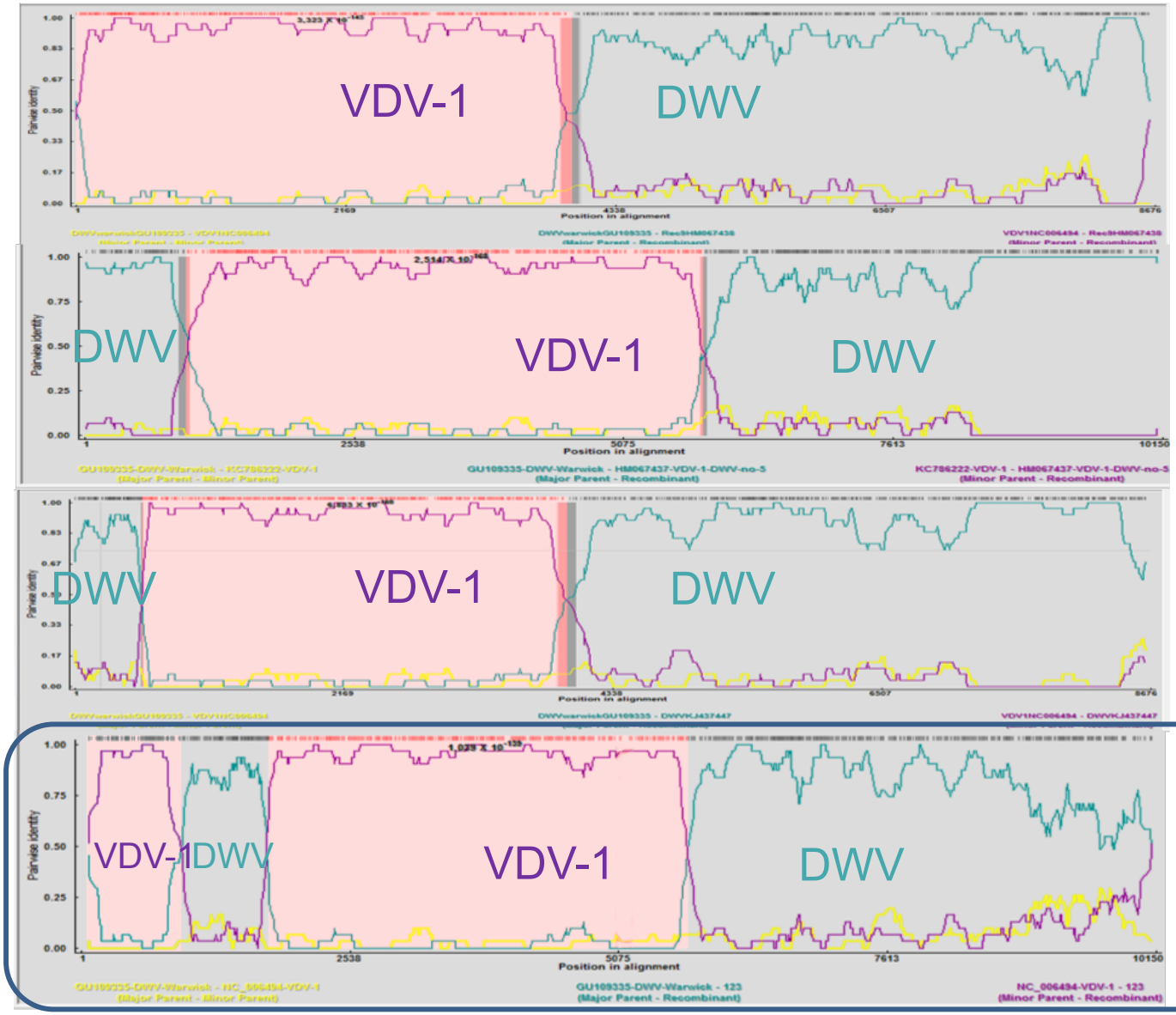
DWV, SBV, BQCV, CBPV,

ABPV, ~~IAPV~~, ~~KBV~~

Log10 (virus copies per bee)



Recombination breakpoints



RDP analysis

HM067438

HM067437

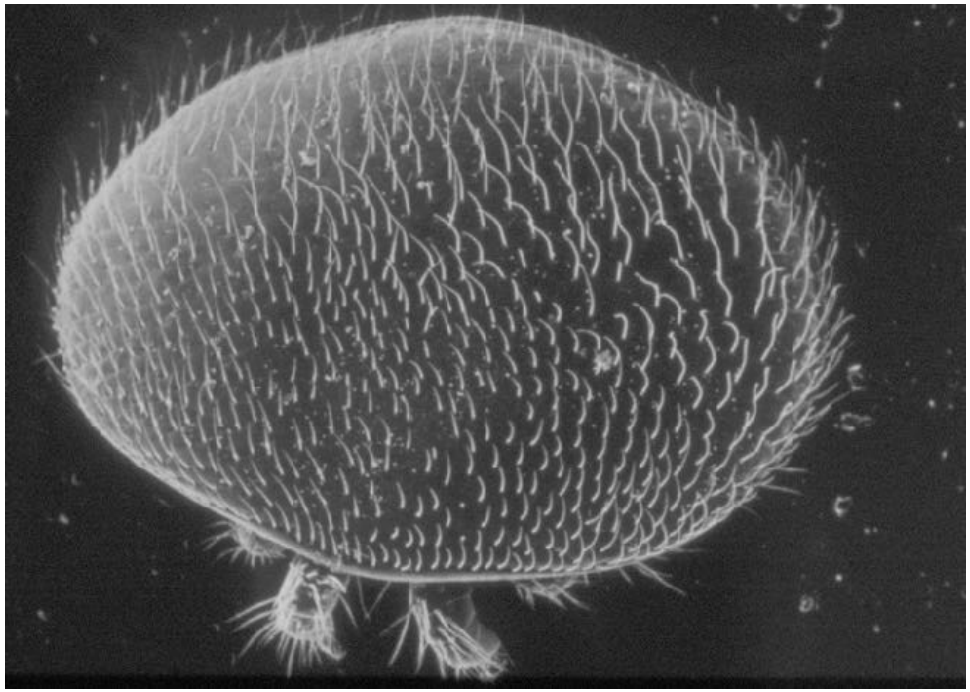
KJ437447

123

Triple recombinant

Hypothesis tested:

Virulence of the varroa mites :

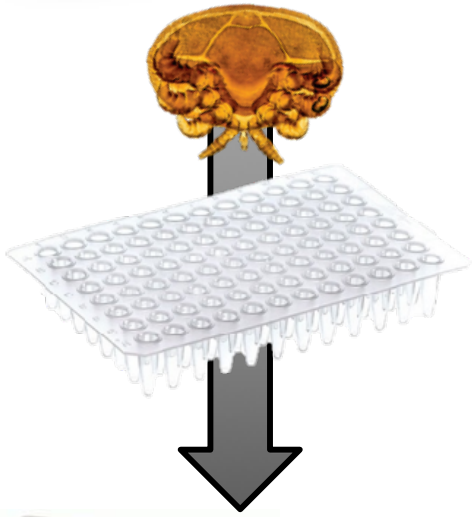


Populationnal markors:

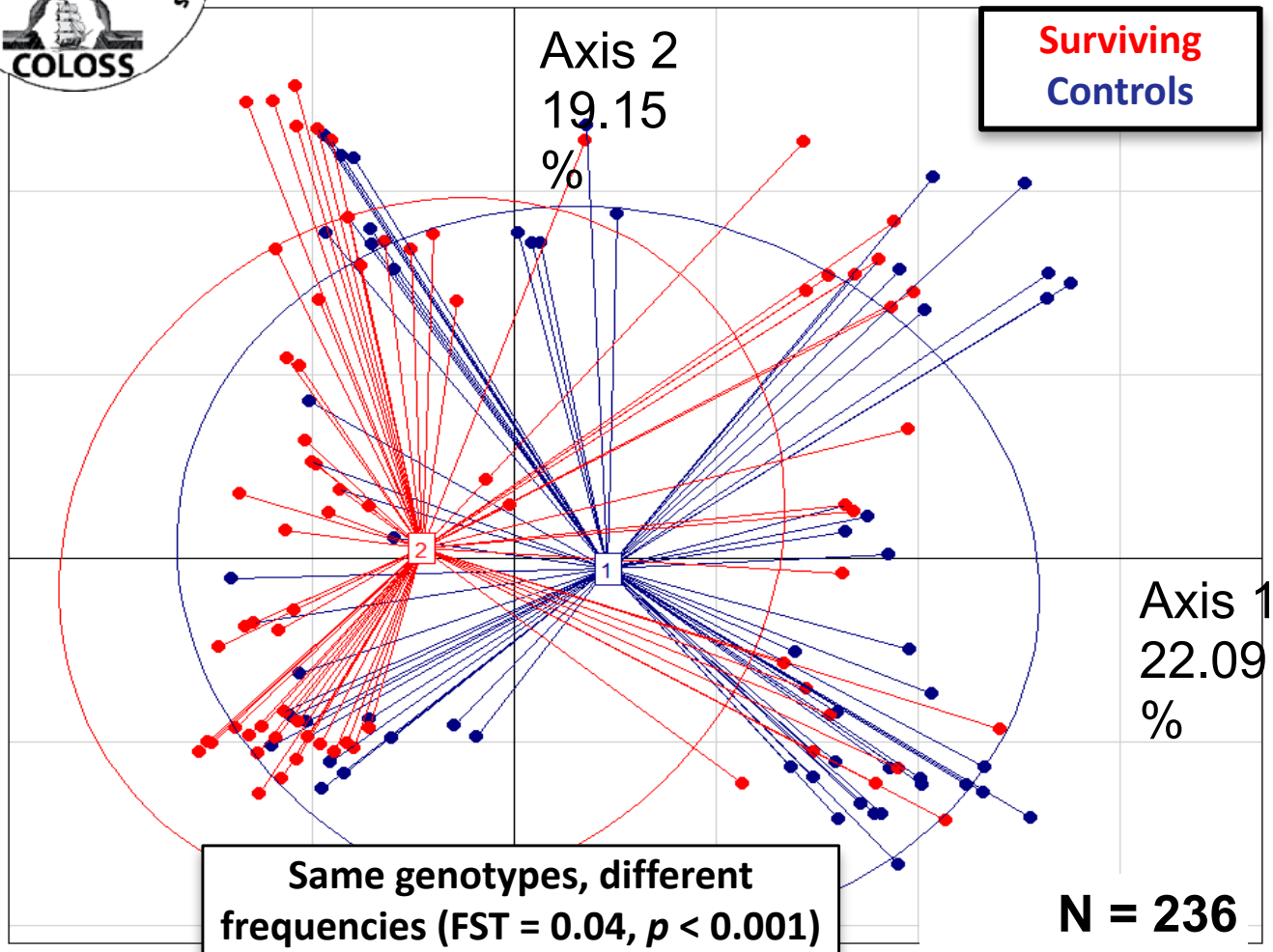
ADNm, complete sequence.

17 microsatellites ADNn

Navajas, M., LeConte, Y., Solignac, M., Cros-Arteil, S. et Cornuet, J-M. 2002. ***Mol. Biol. Evol.*** 19: 2313-2317.



9 microsatellites



Same genotypes, different frequencies (FST = 0.04, $p < 0.001$)

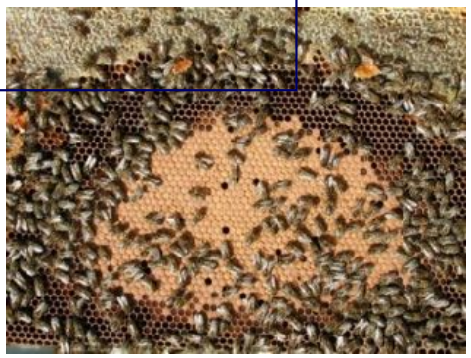
N = 236 varroas

Moro, A., Blacquière, T., Dahle, B., Dietemann, V., Le Conte, Y., Locke, B., Neumann, P., Beaurepaire, A., 2021. Ecology and Evolution, 1-13

Survival of the honey bee colonies

Confirmed

Lessons we can take



In France,

Le Conte & al 2007. Apidologie 38:1–7.
Kefuss et al, (2005, 2009)
Ile de Groix

In Sweden,

Fries I, Imdorf A, Rosenkranz P. 2006. Apidologie 37:564-70

In Norway

In Americas : on africanized bees: *Mondragon &al 2005. Apidologie 36:345-58.*

US: *Seeley TD. 2007. Apidologie 38:19-29.*

Puerto Rico: *Gentle Africanized bees (GAFB) Giray Tugrul & al, Evolutionnary Application 2012*

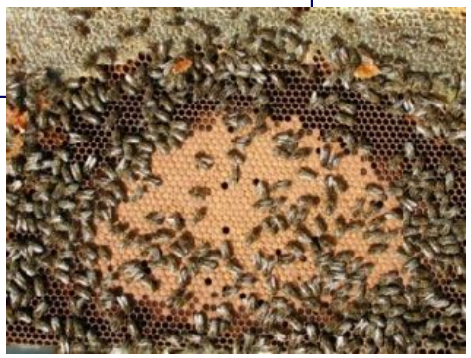
Belgrade: *Bila Dubai´c, J & al, Insects 2021, 12, 1127*

Africa

More and more cases!!

Survival of the honey bee colonies

Lessons we can take

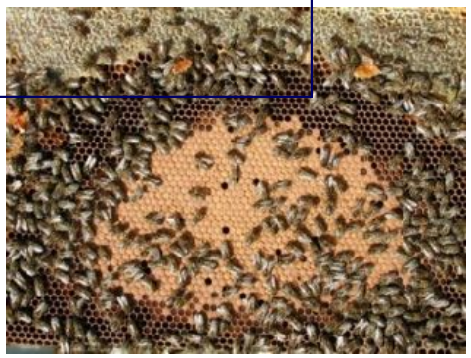


Different mechanisms:

- ? Individual and social immunity
  - ❑ Olfaction, propolis
  - ❑ viruses ?
- ? Varroa reproduction and / or VSH and uncapping behavior
- ? Swarming
- ? Mites
- ? ….

Survival of the honey bee colonies

Lessons we can take



In France,

In Sweden,

Different mechanisms ??

In Norway

In Americas

In Puerto Rico

Etc…….

Main drivers in the different populations?

Modelling approach ?

- Beekeeping : Need for selection of varroa resistant bees

Selection on chosen characters: VHS, the most promising

Varroa hygienic behavior: Realistic

INRAE

Selection of varroa resistant bees:

A real hope with VSH bees!!

But **phenotyping is time consuming**!

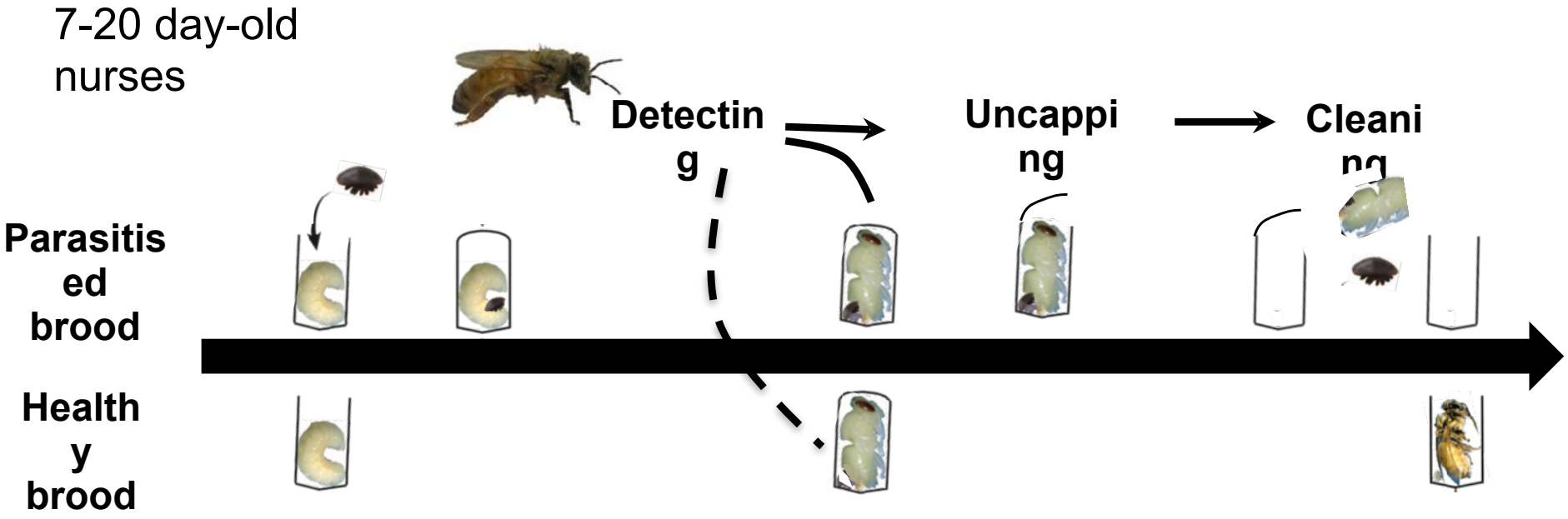
how can we do?

Institut National de la Recherche Agronomique

Selection of varroa resistant bees:

VSH

Recapping



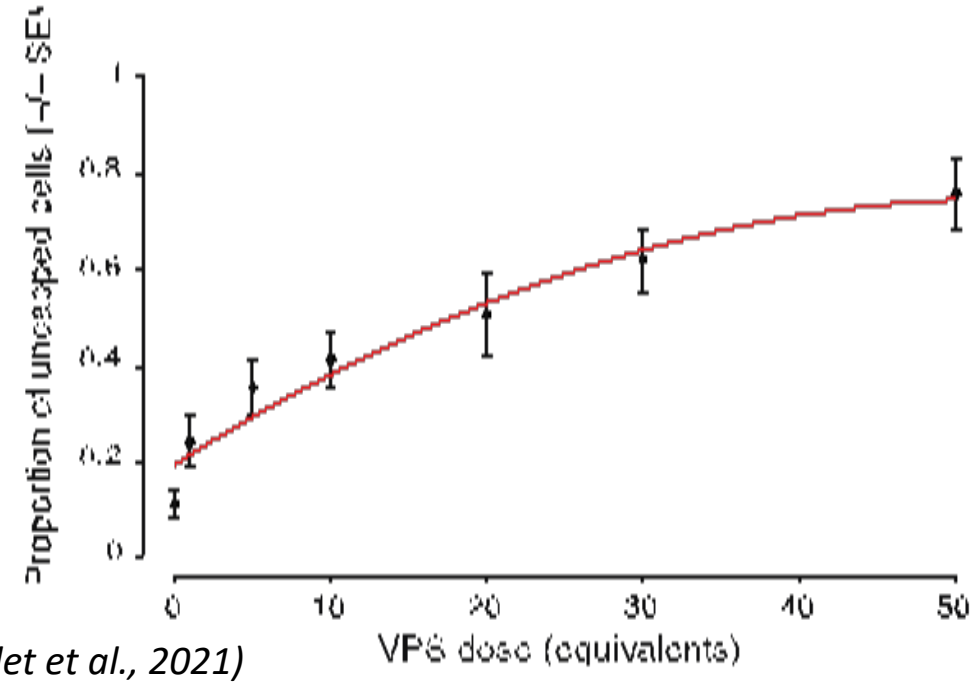
Using chemicals produced by infested cells

Search for such compounds: applications in beekeeping

INRAE

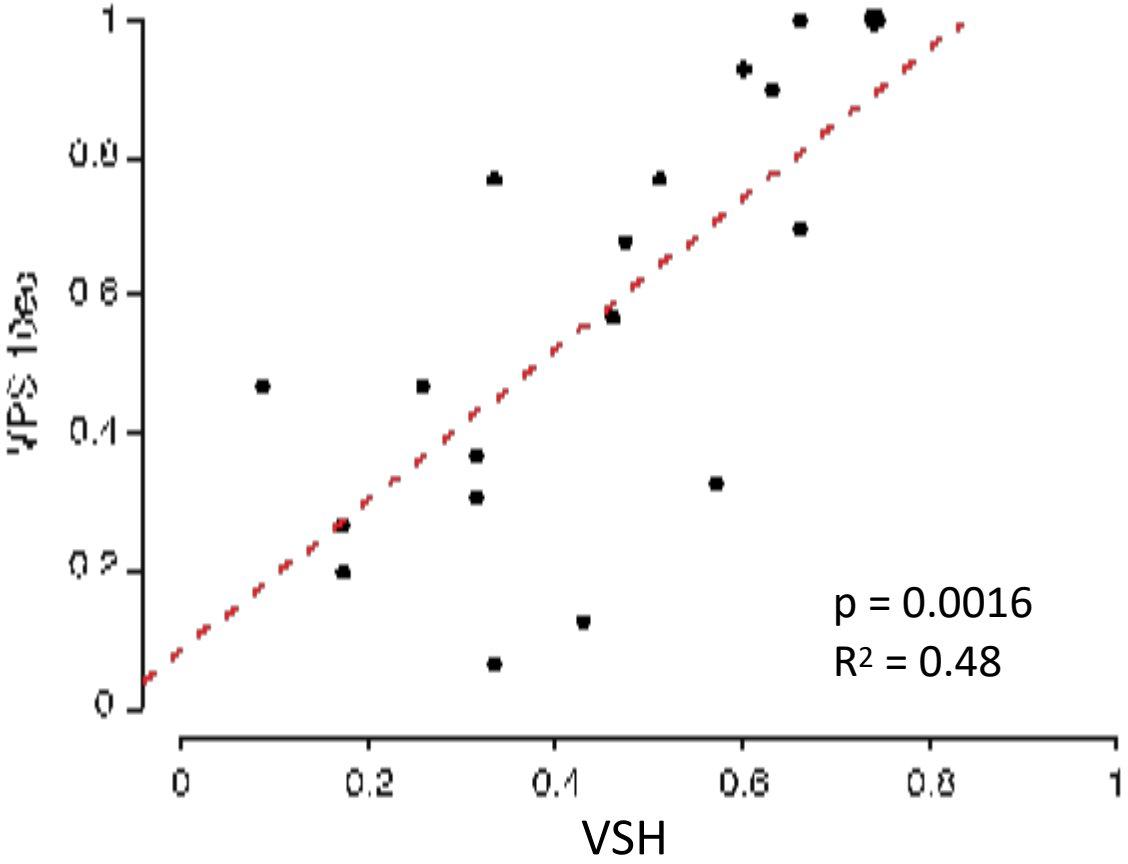
Compounds triggering VSH

- **A long chemical ecology journey…**



(Mondet et al., 2021)

VPS activity and resistance diagnostic



(Mondet et al., 2021)

Selection of varroa resistant bees:

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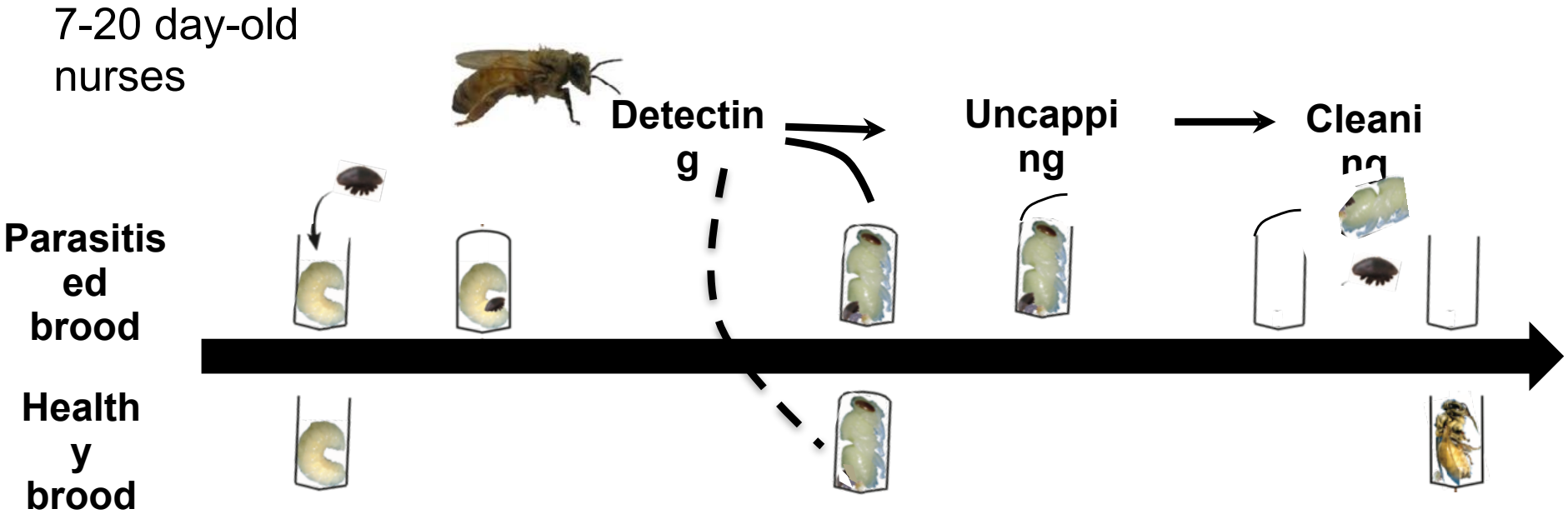
Recapping



Molecular markers for selection (SNPs Single Nucleotid Polymorphism)

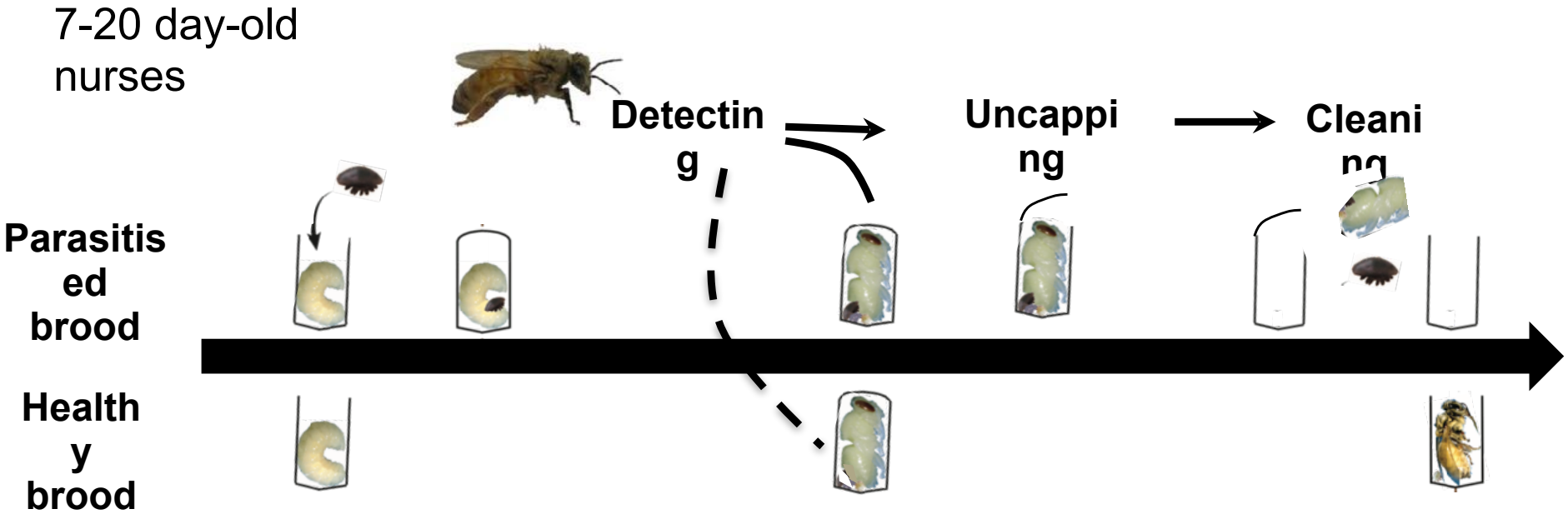
Using sequensing of VSH versus non VSH bees to find those SNPs

INRAE

Selection of varroa resistant bees:

VSH

Recapping



Using both technics?

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Congratulations!

They can do it ! A real hope !

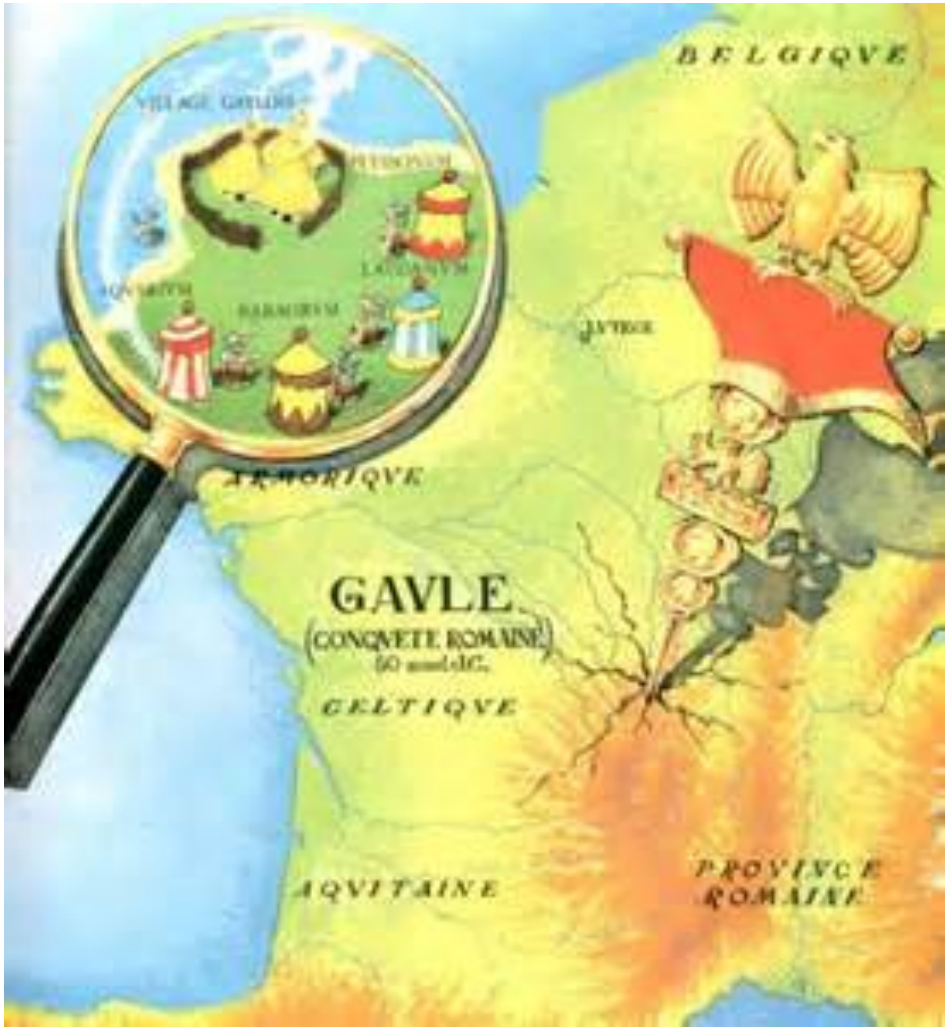
Scientists

Apis cerana

Apis mellifera

- Natural Selection of varroa resistant bees

2007



Untreated colonies survive in France ???

INRAE

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PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

PLANT B