



# Understanding the impact of climate change and pest outbreaks on fruit trees: towards a sustainable conservation of wild species relatives to domesticated fruit trees

**Amandine CORNILLE**

Full time CNRS researcher

Quantitative Genetic & Evolution lab – Le Moulon



Génétique  
Quantitative  
et Évolution  
Le Moulon

[amandine.cornille@gmail.com](mailto:amandine.cornille@gmail.com)



@CornilleAmand



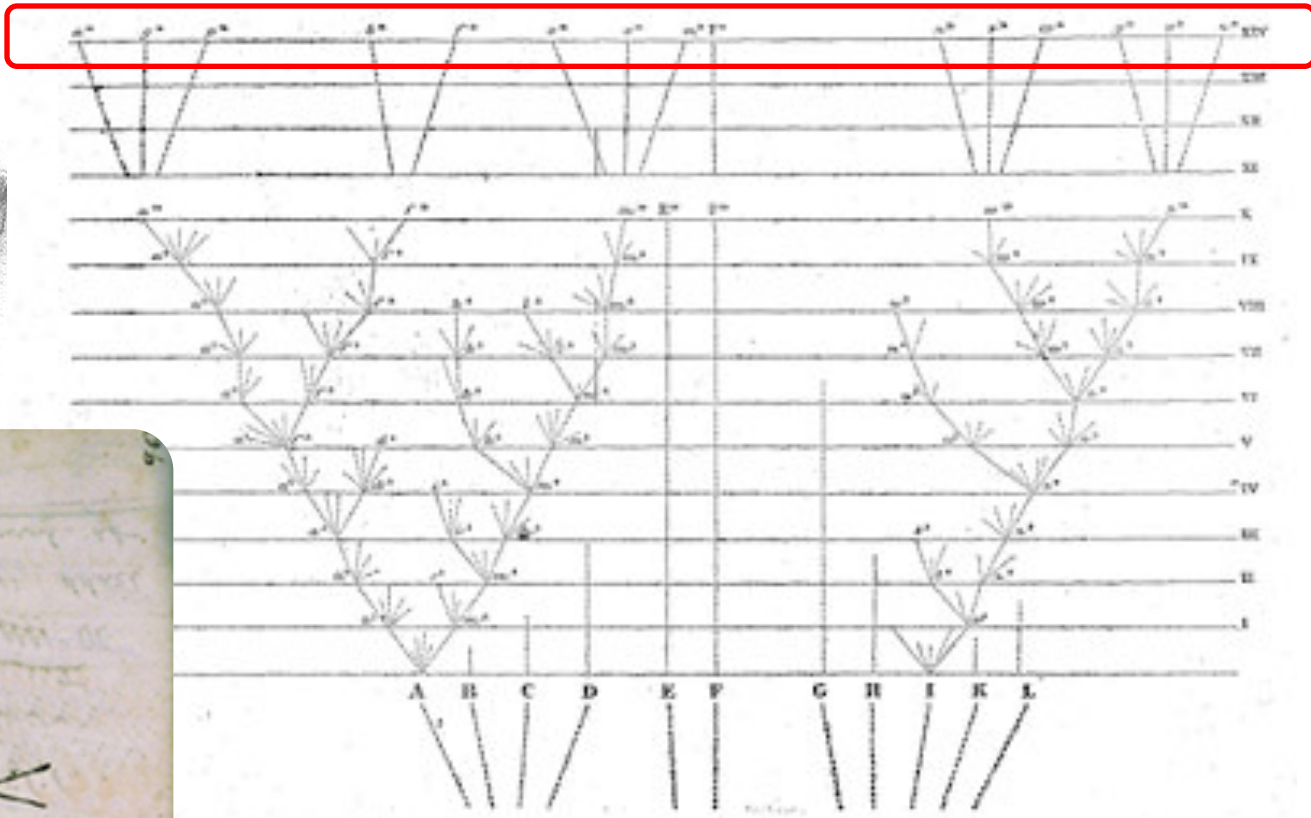
## A collage of various plants and a central image of Charles Darwin with a question mark. The collage includes: green figs on a branch; yellow sunflowers; a field of tall grass with orange seed heads; a large, dark, spiky plant; a tree with a large, exposed root system on a beach; a field of yellow wheat; a purple globe thistle; a cluster of white flowers; a pink peony; a Bird of Paradise flower; a green apple; a pink dahlia; a Venus flytrap; a white daisy-like flower; a red and yellow tulip; a large green tree; a close-up of a grass seed head; a yellow and red orchid; and a large, gnarled tree trunk in a field. In the center is a black and white portrait of Charles Darwin with a large white question mark overlaid on it.



# Evolutionary processes shaping diversity and divergence?



## Varieties, populations, species



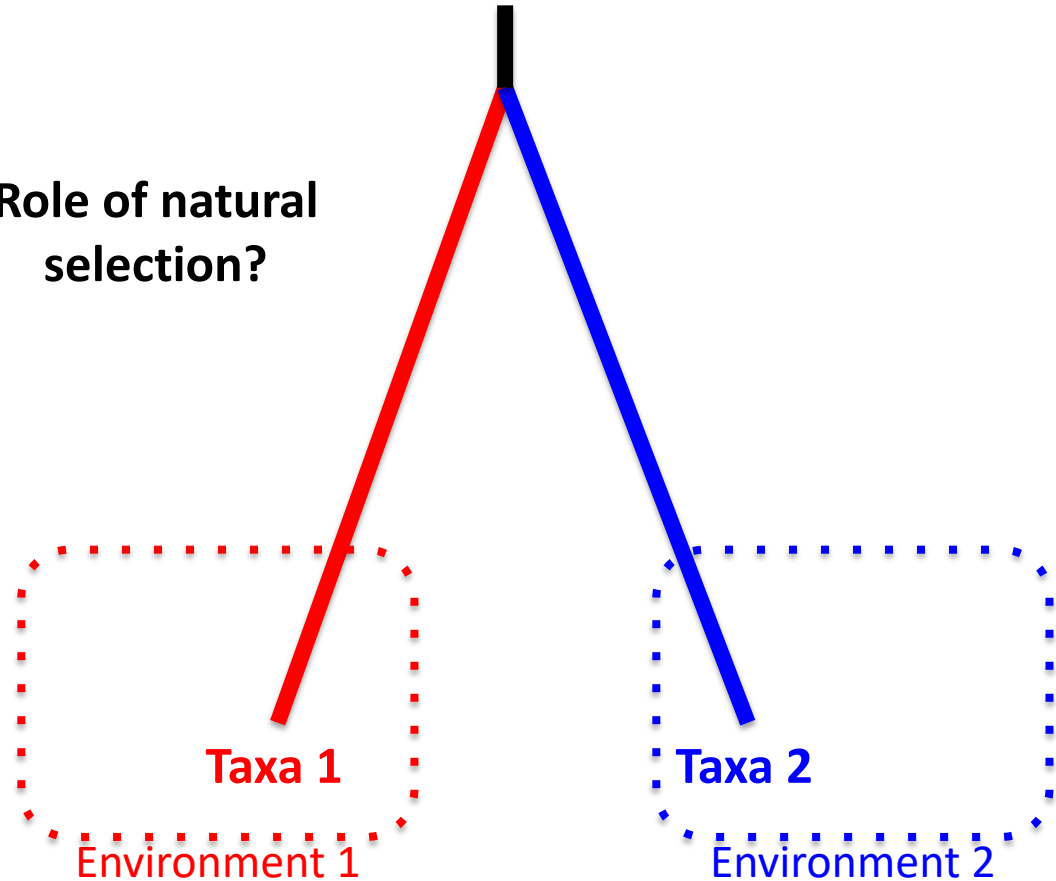


# Evolutionary processes shaping diversity and divergence?



Divergence histories among evolutionary lineages?

Role of natural selection?





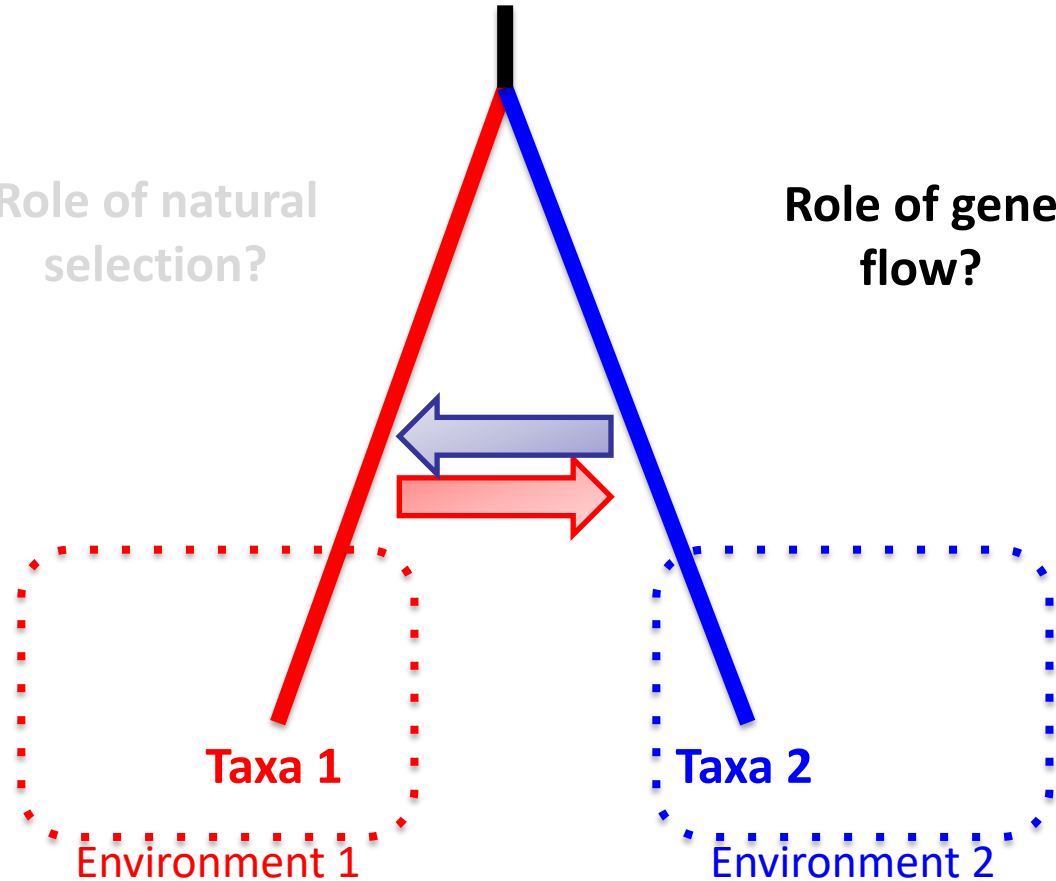
# Evolutionary processes shaping diversity and divergence?



Divergence histories among evolutionary lineages?

Role of natural  
selection?

Role of gene  
flow?





# Evolutionary processes shaping diversity and divergence?

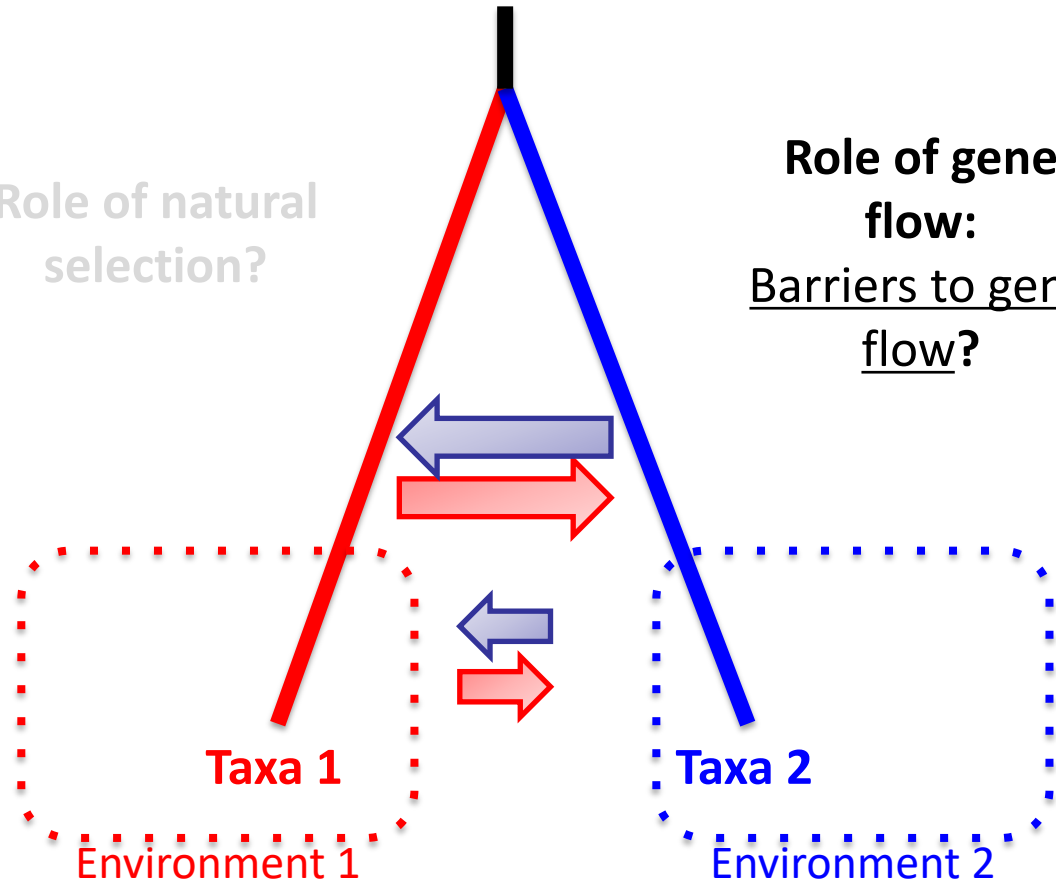


Divergence histories among evolutionary lineages?



Role of natural  
selection?

Role of gene  
flow:  
Barriers to gene  
flow?





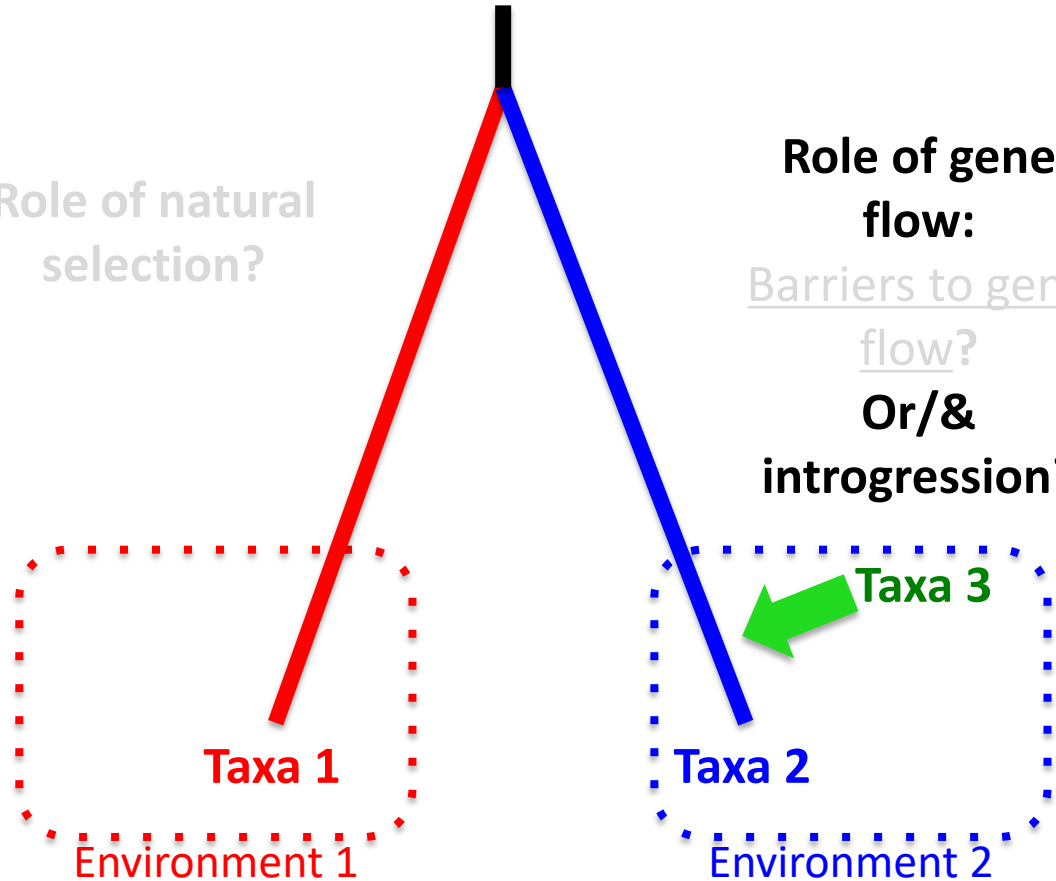
# Evolutionary processes shaping diversity and divergence?



Divergence histories among evolutionary lineages?

Role of natural  
selection?

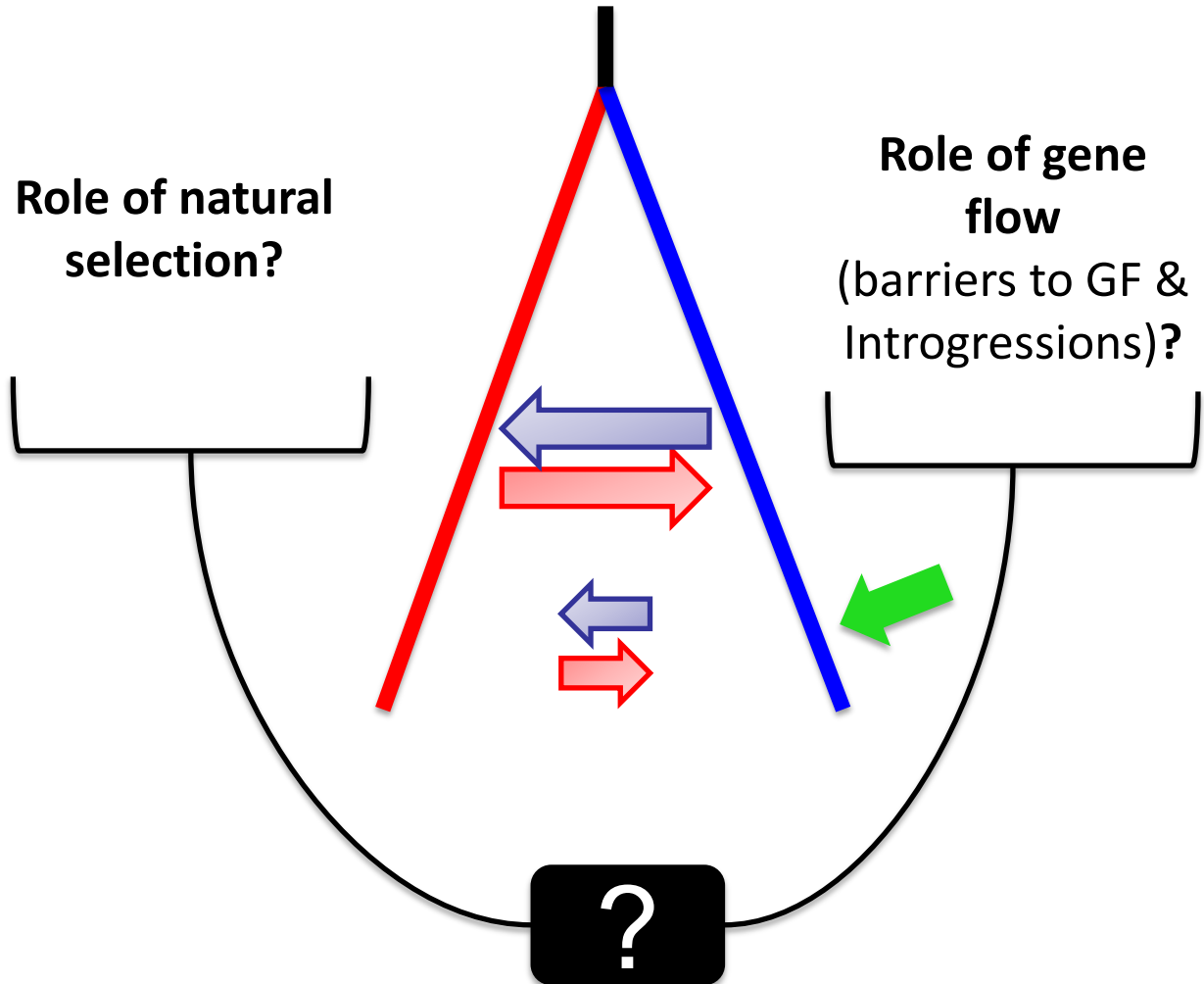
Role of gene  
flow:  
Barriers to gene  
flow?  
Or/&  
introgression?



# Evolutionary processes shaping diversity and divergence?



Divergence histories among evolutionary lineages?

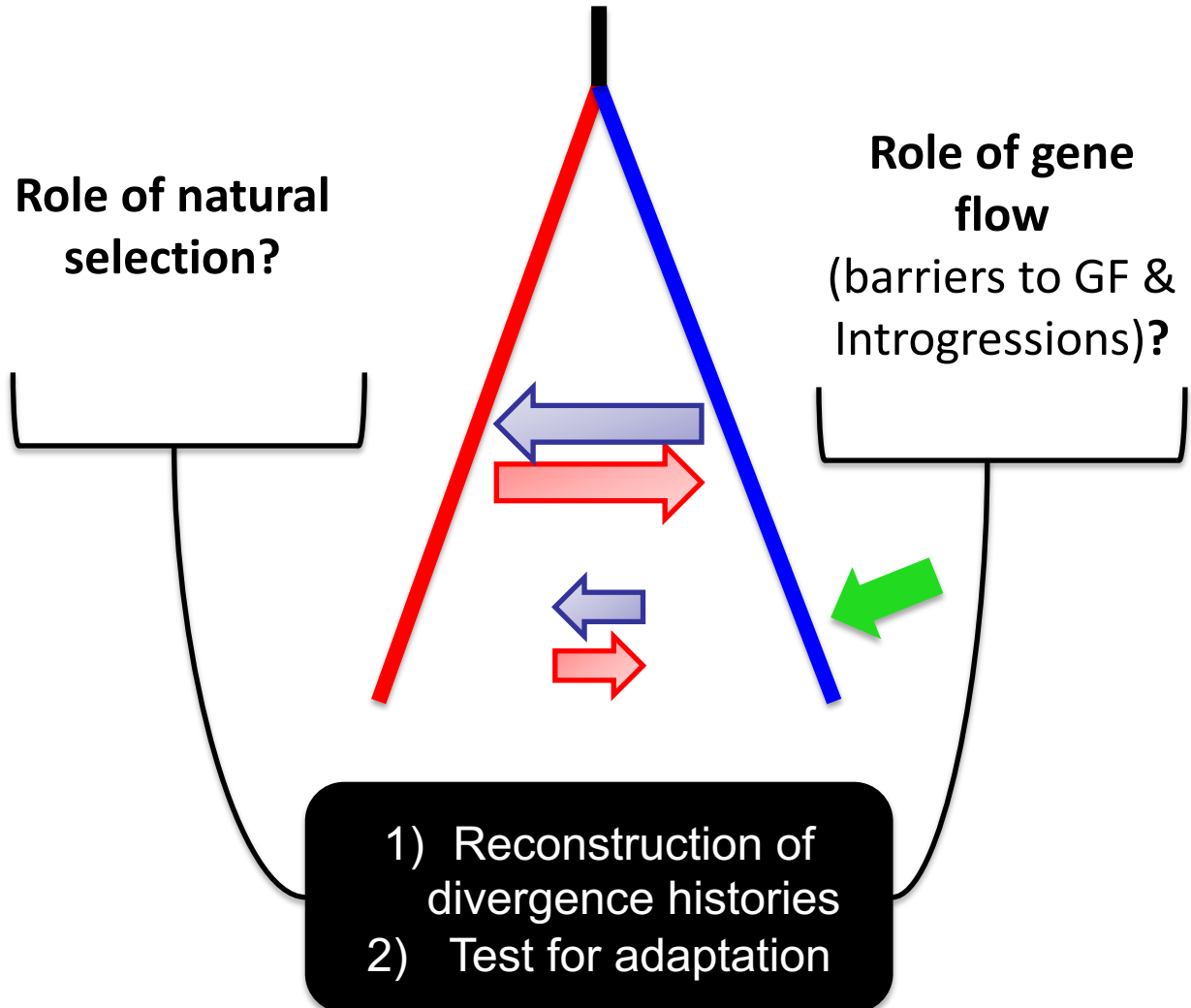




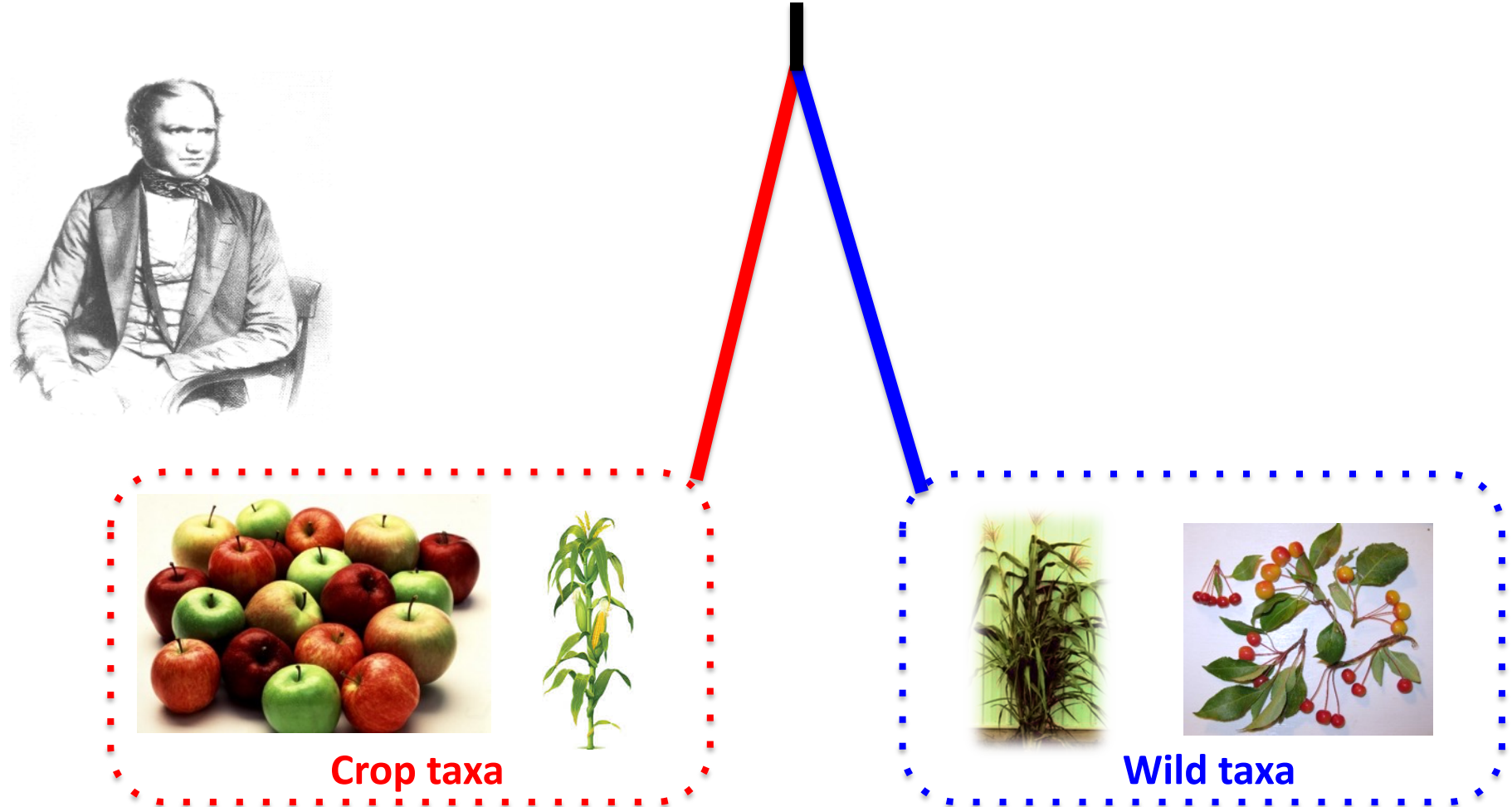
# Evolutionary processes shaping diversity and divergence?



## Divergence histories among evolutionary lineages?



# Domestication: a very good model to unravel evolutionary processes at play during divergence





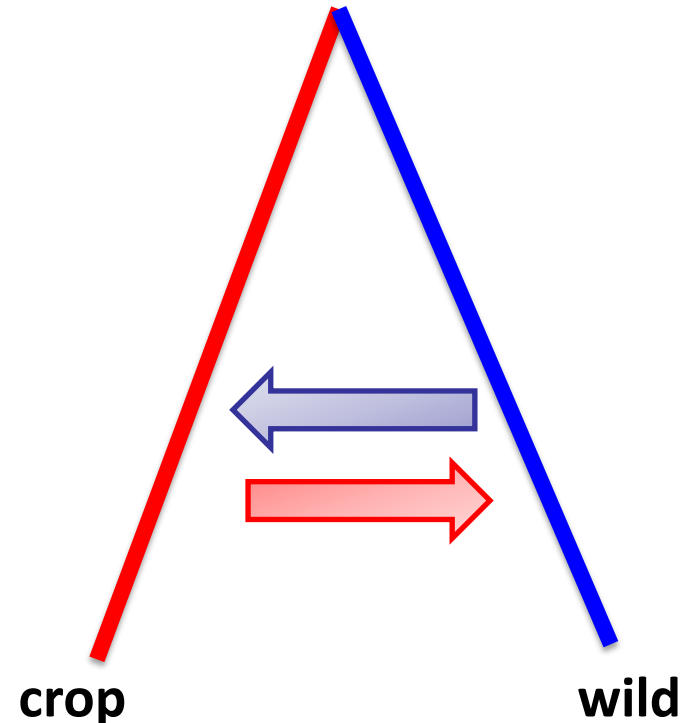
# Domestication: a very good model to unravel evolutionary processes at play during divergence



**Selection for agronomic traits**



**Gene flow**

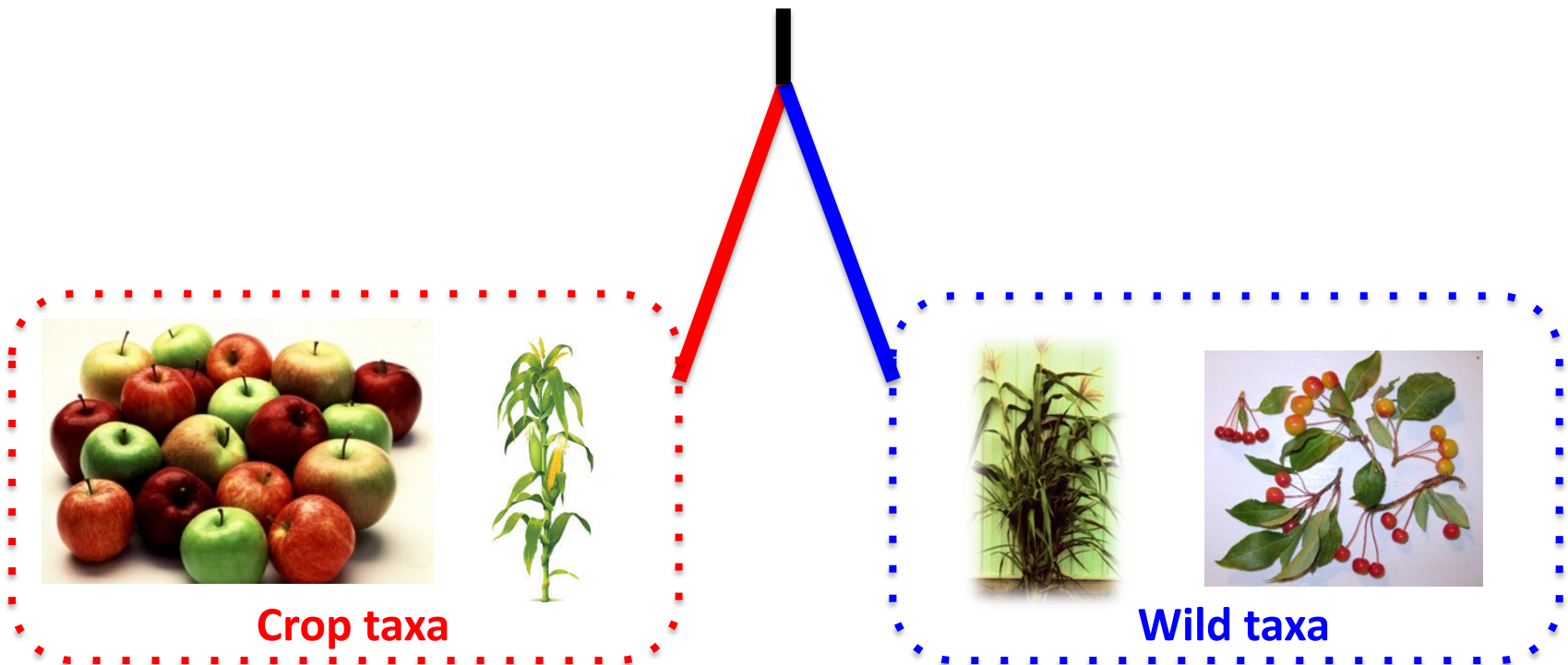


# Domestication: a very good model to unravel evolutionary processes at play during divergence

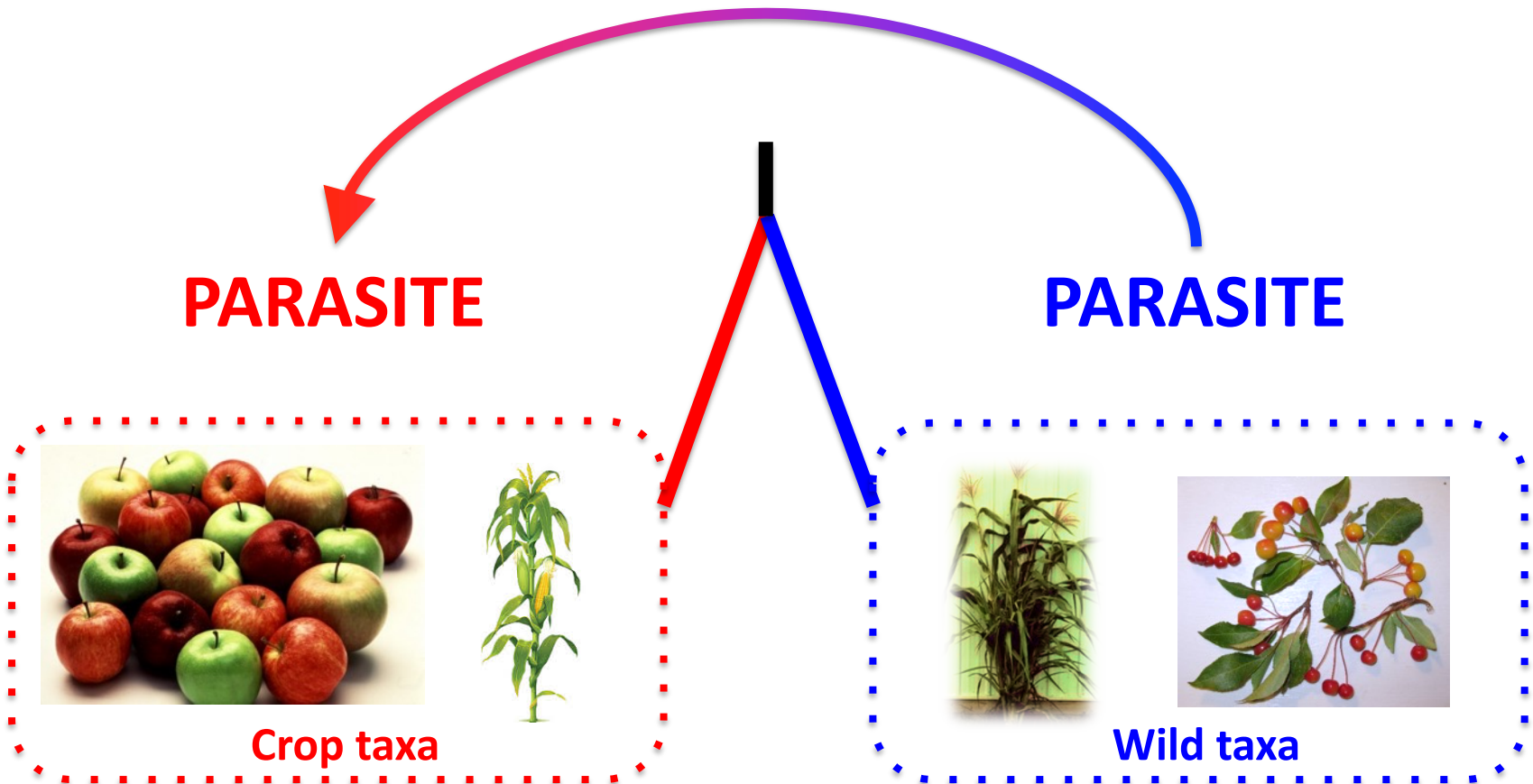




# Crop parasite adaptive divergence by host shift during plant domestication

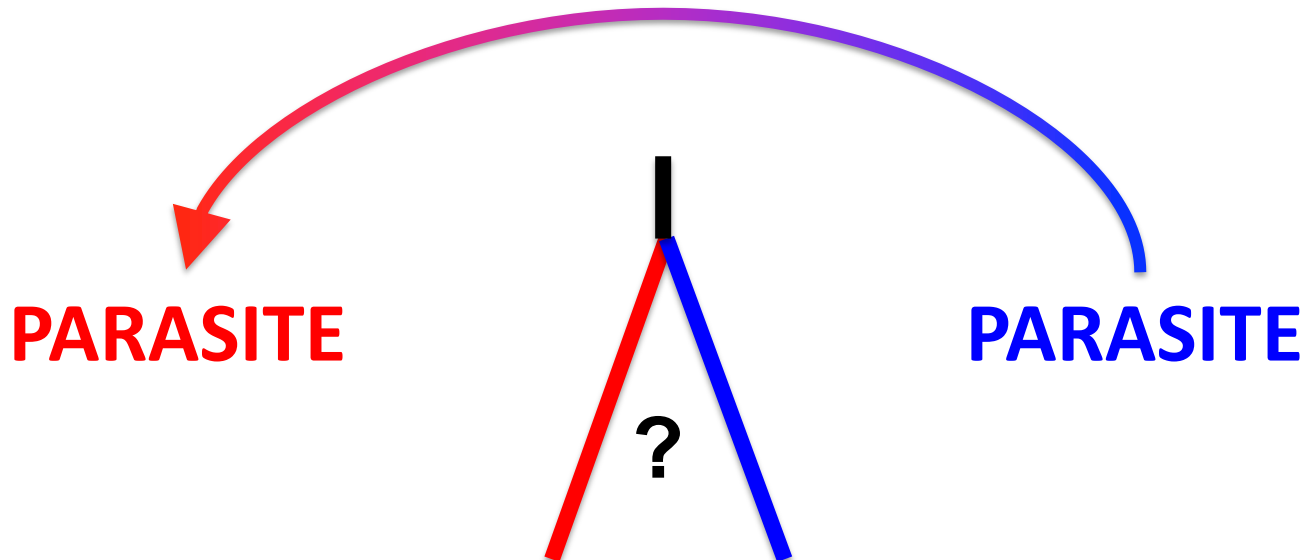


# Crop parasite adaptive divergence by host shift during plant domestication



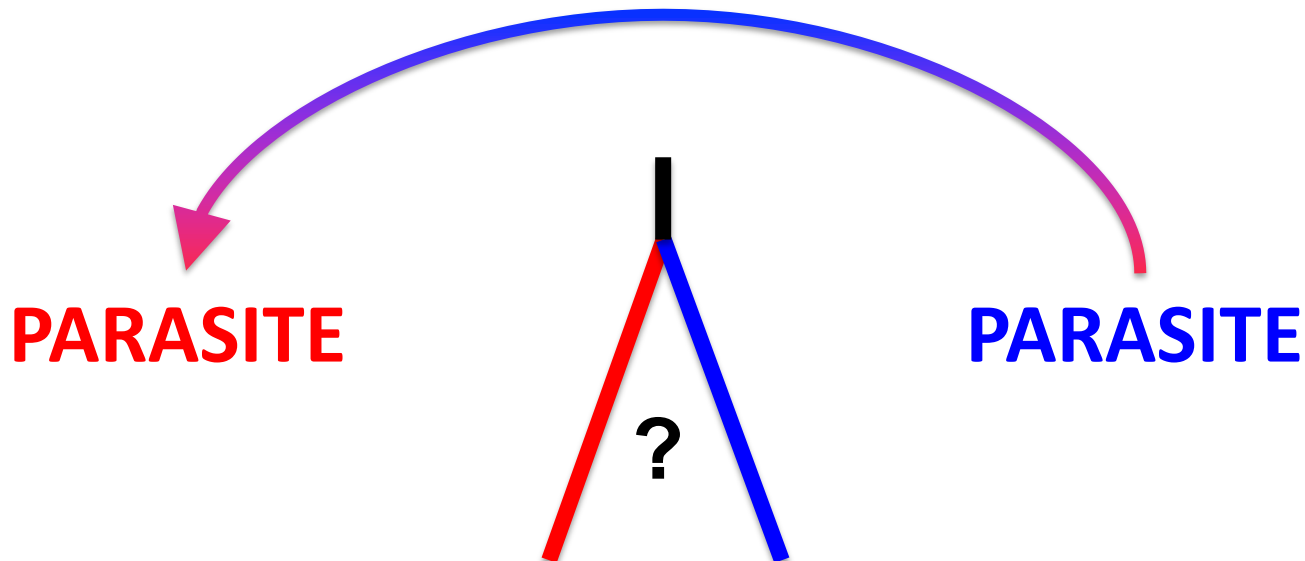


# Crop parasite adaptive divergence by host shift during plant domestication



1. How changes in selection associated to domestication have affected the coevolutionary dynamic and genome structures?

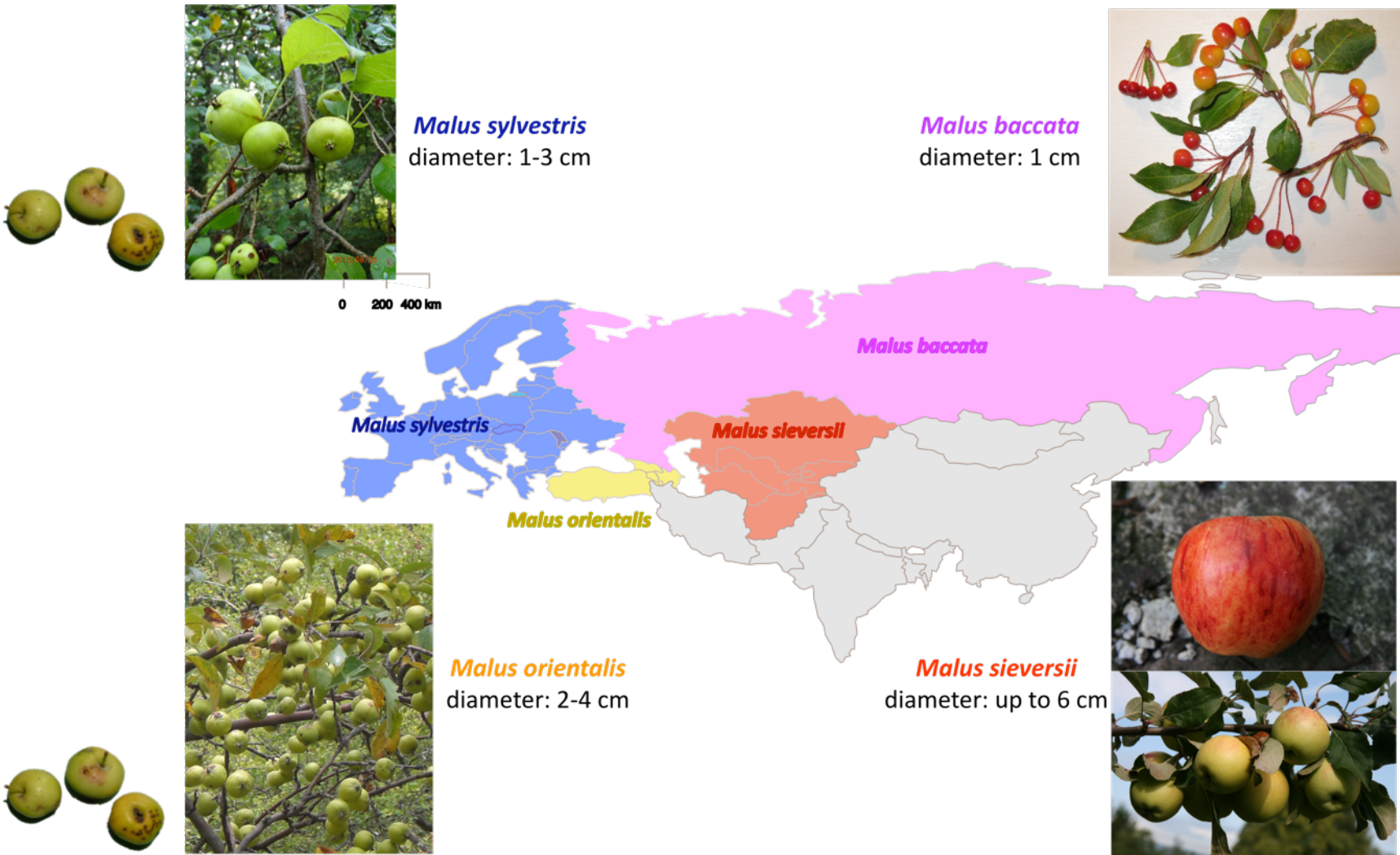
# Crop parasite adaptive divergence by host shift during plant domestication



1. How changes in selection associated to domestication have affected the coevolutionary dynamic and genome structures?

2. Have these changes led to the adaptive divergence of the parasite?

# Adaptive genomics of apple-aphid interaction in the context of domestication (i.e. recent divergence)





# Adaptive genomics of apple-aphid interaction in the context of domestication (i.e. recent divergence)



*Malus sylvestris*  
diameter: 1-3 cm



*Malus sylvestris*

*Malus*



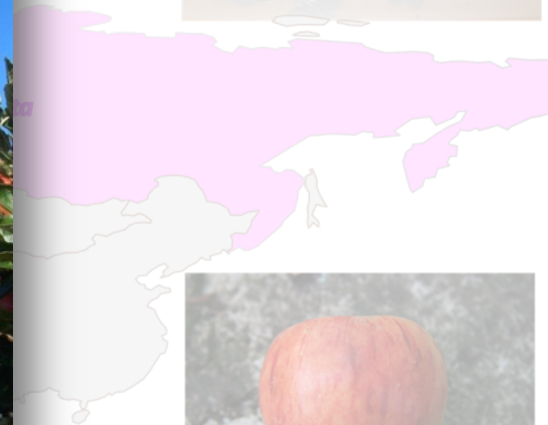
*Malus orientalis*  
diameter: 2 cm



*Malus baccata*  
diameter: 1 cm



+ *Malus domestica*  
The cultivated apple



*Malus sieversii*  
diameter: up to 6 cm



# Adaptive genomics of apple-aphid interaction in the context of domestication (i.e. recent divergence)



*Malus sylvestris*  
diameter: 1-3 cm

0 200 400 km



*Malus baccata*  
diameter: 1 cm



*Dysaphis plantaginea*

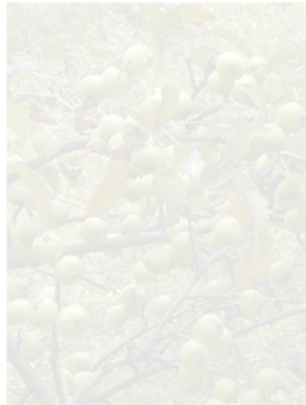
The rosy apple aphid

*Malus sylvestris*

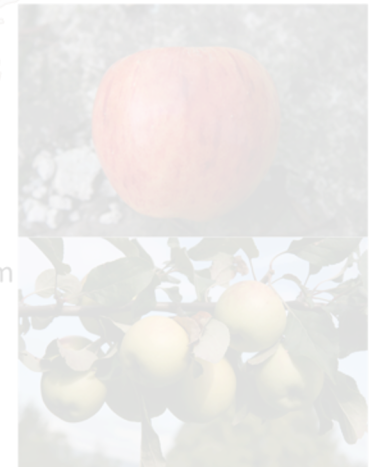
*Malus baccata*

*Malus sieversii*

*Malus orientalis*

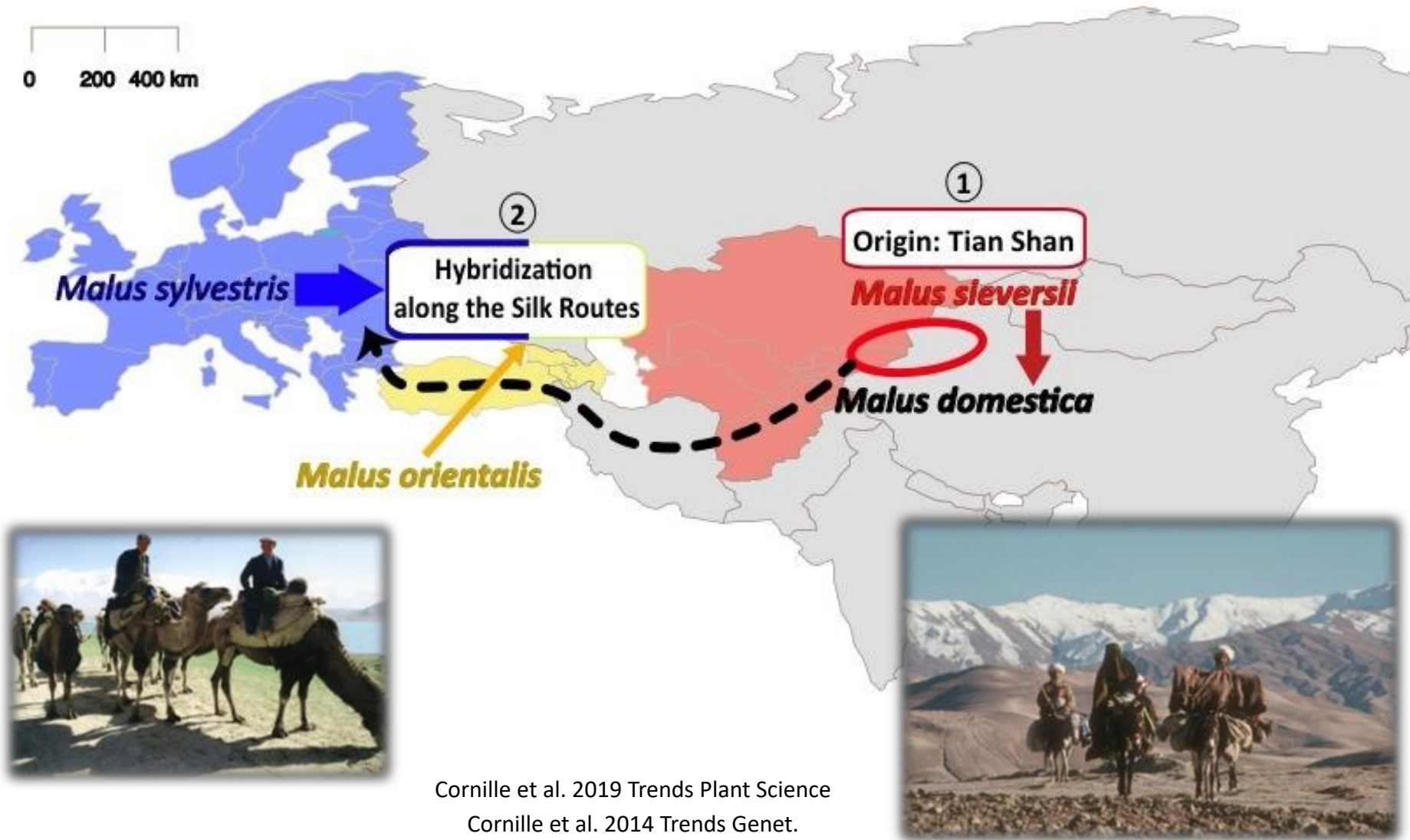


*Malus orientalis*  
diameter: 2-4 cm



*Malus sieversii*  
diameter: up to 6 cm

# Important secondary contribution of the European wild apple tree *M. sylvestris* to the cultivated apple tree *M. domestica*





# Conversely, frequent introgressions from the cultivated apple tree *M. domestica* into the wild European apple tree *M. sylvestris*



*M. domestica*



Crop-to-wild  
introgressions



wild-to-crop  
contribution



*M. sylvestris*



**Major secondary contributor  
to the cultivated apple**

(Cornille et al. 2012, PloS Genet.)

# Five main genetic groups for the European wild apple

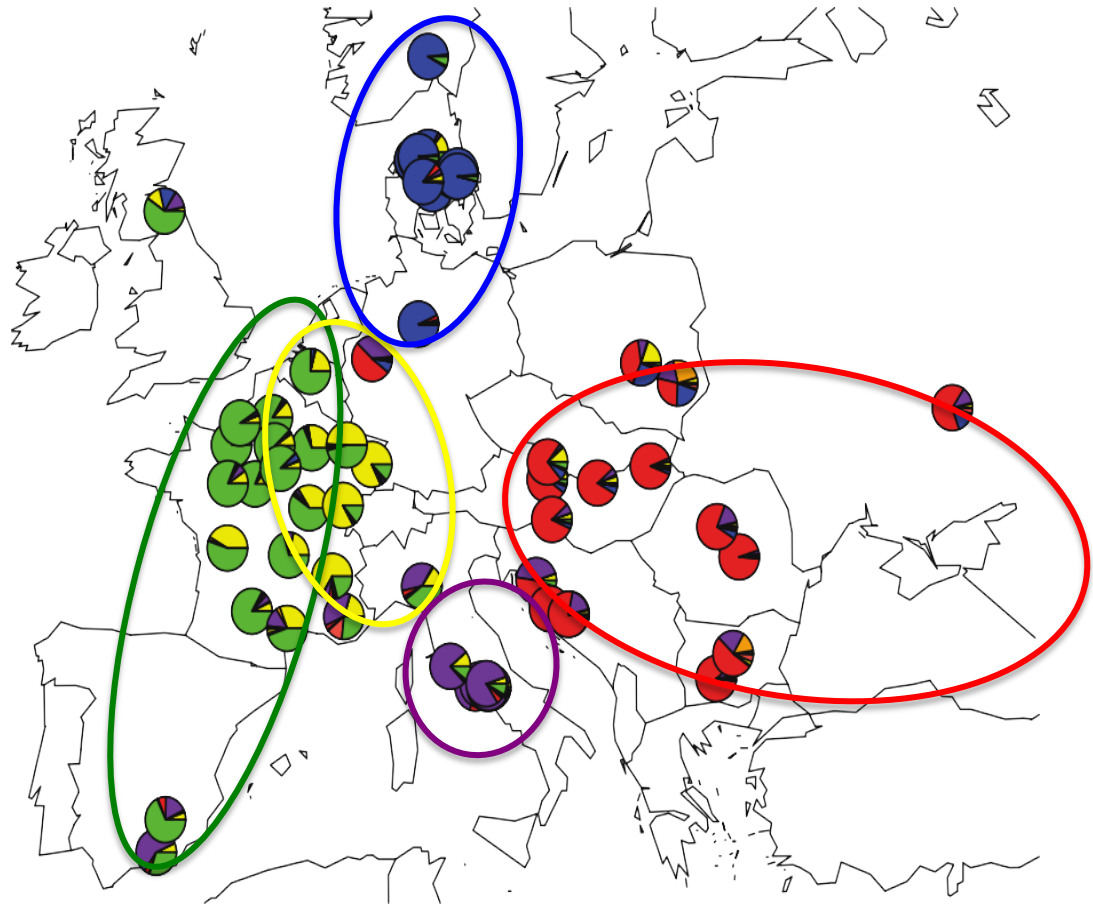
Important to take into account when replanting wild apple trees



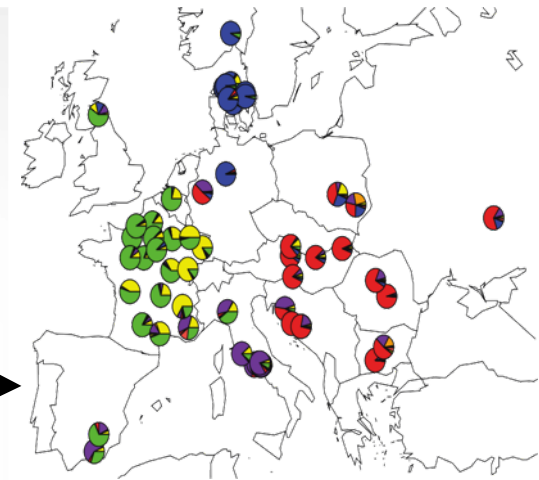
-20,000 ya



Nowadays



# Conservation and experimental orchard of *Malus sylvestris* at University Paris Saclay



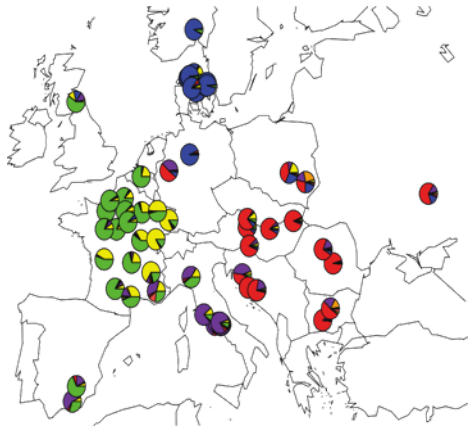
Plantation of **400 wild apple trees** from the **five genetic groups**





# 1800 wild apples : October 2019

Genotyped for 26 microsatellite markers





# 1800 wild apples : October 2020





# Nov 2020: Orchard now planted on the Saclay plateau!


 @PommierVerger

Merci à toutes et à tous!!!





# Yesterday: Pedologic pedagogic hole and fences settled!

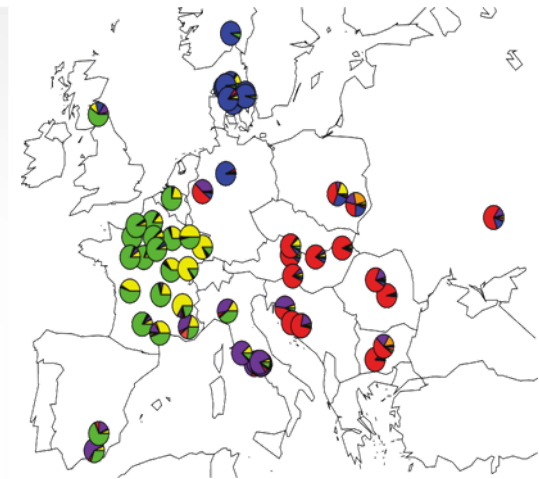
 @PommierVerger



Cécile Quantin, GEOPS



# Conservation and experimental orchard of *Malus sylvestris* at University Paris Saclay



Plantation of 400 trees  
from the five  
genetic groups

- **Experimental stations** for testing fruit tree **adaptation to climate and pathogens**
  - **Ex-situ source of apple seeds and/or scions**  
for conservation & breeding programs
  - **Training and divulgation center** of agroforestry  
for colleges of agriculture and for students from Universities



# SYNERGY among local and national stakeholders

## SOON: REPLICATES in France!!!!

université  
PARIS-SACLAY

FACULTÉ  
DES SCIENCES  
D'ORSAY

INRAE

cnrs

AgroParisTech  
INSTITUT DES SCIENCES ET INDUSTRIES DU VIVANT ET DE L'ENVIRONNEMENT  
PARIS INSTITUTE OF TECHNOLOGY FOR LIFE, FOOD AND ENVIRONMENTAL SCIENCES

Agence  
des Espaces  
Verts

LabEx  
BASC  
Biodiversité, Agroécosystèmes,  
Société, Climat

DANONE  
NUTRICIA  
RESEARCH

Bouture.com



IDEEV  
Institut Diversité, Ecologie et Evolution du Vivant

Interreg  
France-Wallonie-Vlaanderen  
PROVERBIO  
UNION EUROPÉENNE  
EUROPEAN UNION

île de France

PARIS-SACLAY

PRO-INSERT

engie  
Entreprises et collectivités

PARIS  
SACLAY  
Communauté d'agglomération



ATIP  
avenir

Office National des Forêts

AGROFORESTERIE  
association française

L'EA  
Les écoles des éco-activités

TÉCOMAH



USDA

ON  
PASSE ▶  
À L'ACTE



université  
PARIS-SACLAY

LA DIAGONALE

s(cube)  
partageons les sciences.



Groupe d'Action Locale  
PLATEAU DE SACLAY  
Porté par Terre&Cité

Terre&Cité  
PAYS DE SACLAY

île de France

l'Europe  
s'engage  
en Ile-de-France  
avec le FEADER



# Responses of wild apple relatives to the cultivated apple to climate changes?



Génétique  
Quantitative  
et Évolution  
Le Moulon

Collab. Stéphane Bazot



Phenotypic plasticity and/or genetic adaptation (fitness, functional traits)?



Stéphane Bazot  
Univ. Paris Saclay



Carine Remoué  
CNRS



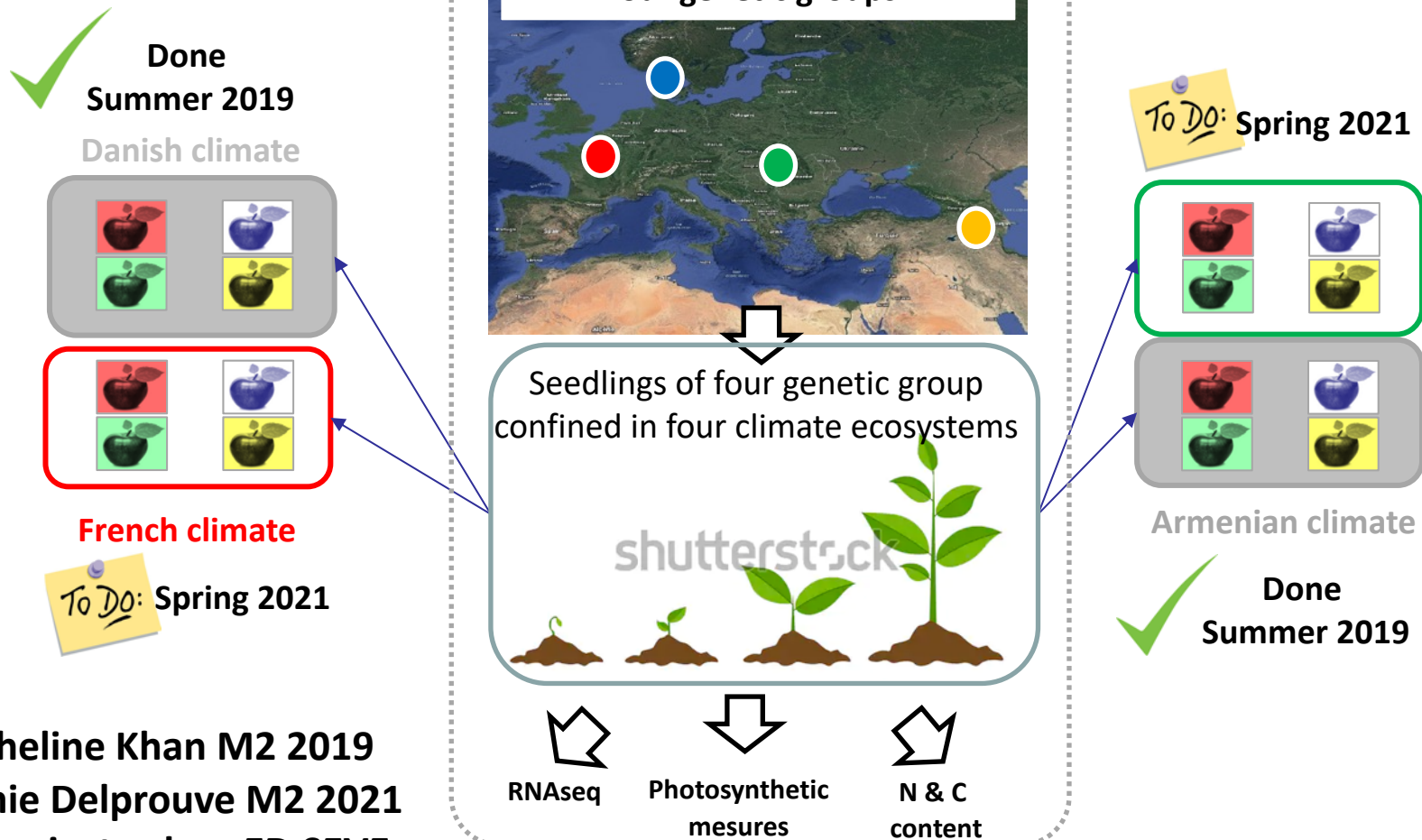
Clémentine Vitte  
Equipe GEVAD





# Responses of wild apple relatives to the cultivated apple to climate changes?

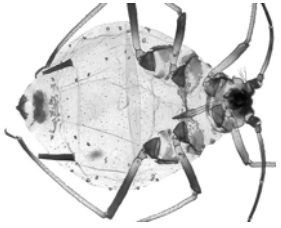
Collab. Stéphane Bazot



Micheline Khan M2 2019

Noémie Delprouve M2 2021

PhD project subm. ED SEVE



# Ongoing project/team

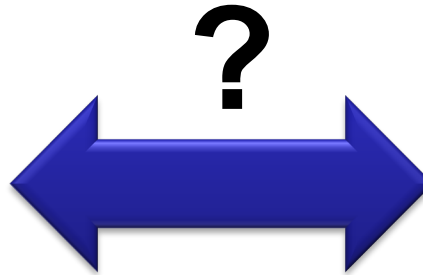
## Aphid-Apple coevolution in a context of domestication



**Rosy Apple Aphid**  
*Dysaphis plantaginea*



**Cultivated apple**  
*Malus domestica*



**Sergio Vazquez, PhD**

**Xilong Chen, postdoc**



**Anthony Venon, M2 (until june 2020)**

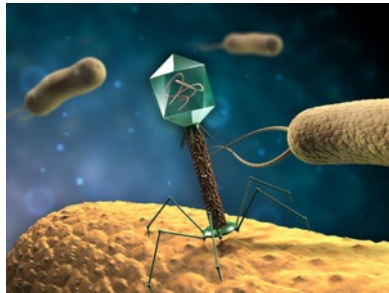
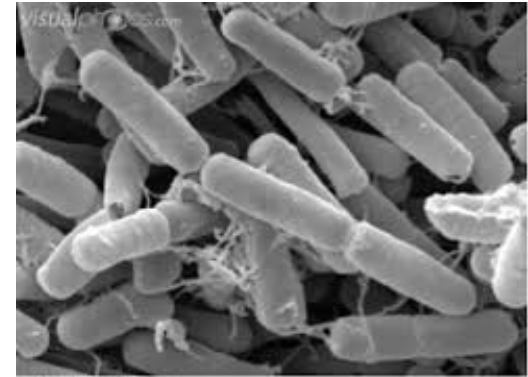


# Host-parasite interactions

Cycle of adaptation and counter adaptation = strong pressure



**COEVOLUTION**





# Ecological genomics of host-parasite interaction ?

Cycle of adaptation and counter adaptation = strong pressure



**COEVOLUTION**

A collage of seven images illustrating various host-parasite interactions: a pink flower with a small insect, a corn leaf with a dark lesion, a mosquito, a microscopic view of bacteria, a fly on a textured surface, a white flower with dark spots, and a corn leaf with yellow lesions.

**FEW EXAMPLES OF RECIPROCAL TRUE COEVOLUTION!!**

**What are the  
ECOLOGICAL AND GENOMIC components?**

# Ecological genomics of host-parasite interaction ?

Cycle of adaptation and counter adaptation = strong pressure

COEVOLUTION

FEW EXAMPLES OF

what are

EVOLUTION!!

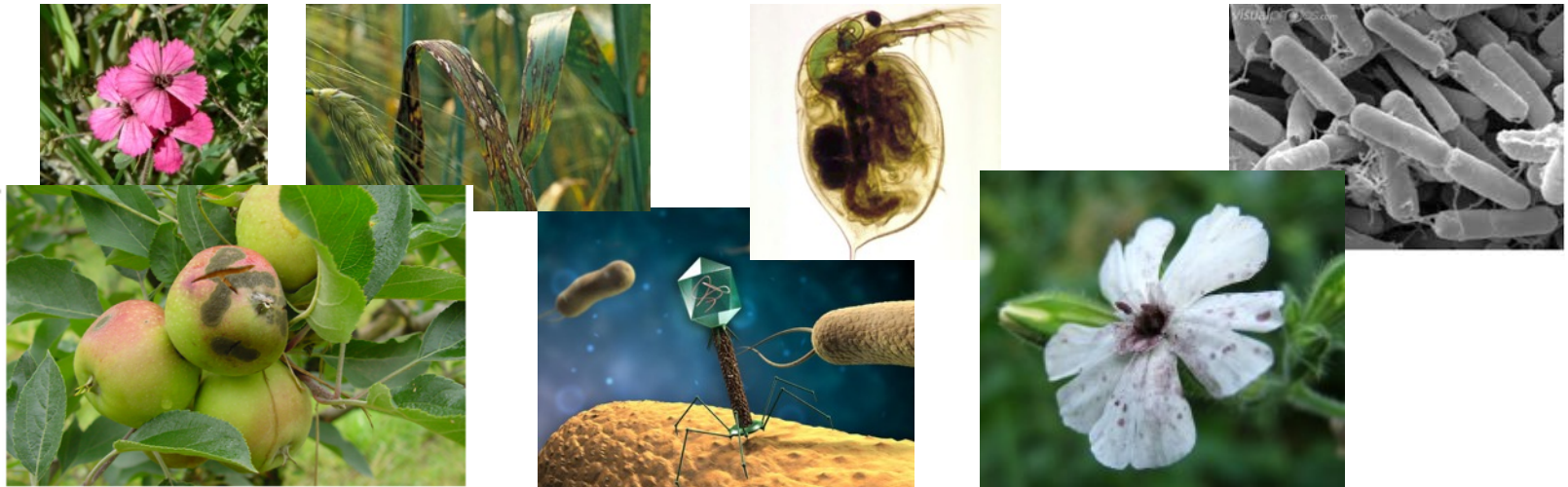
GENOMIC





# Ecological genomics of host-parasite interaction ?

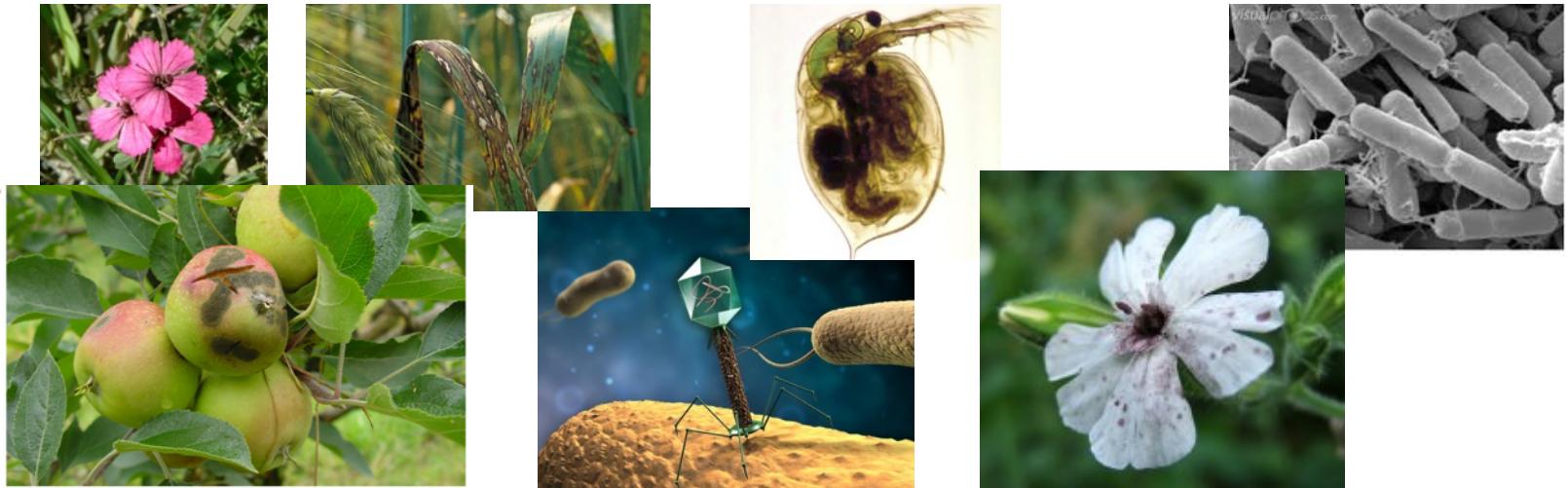
## 1. How many and which genes are involved in coevolution?





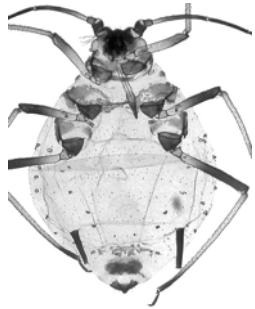
# Ecological genomics of host-parasite interaction ?

## 1. How many and which genes are involved in coevolution?



## 2. Can coevolution ultimately lead to local adaptation, lineage divergence, and ecological speciation, through adaptive divergence?

# The rosy apple aphid, *Dysaphis plantaginea*



**Most damageable species of  
apple production**



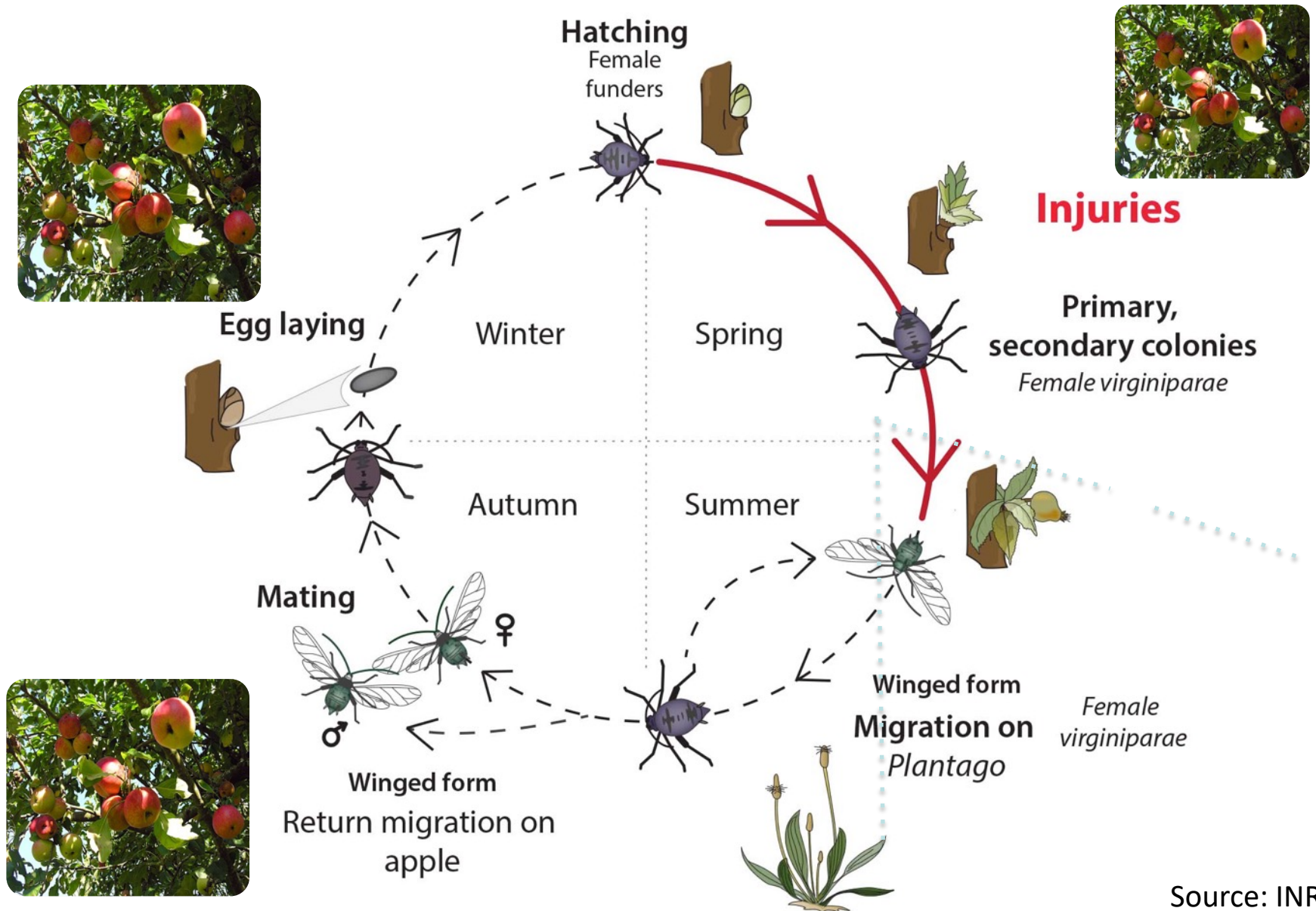


# The rosy apple aphid, *Dysaphis plantaginea*

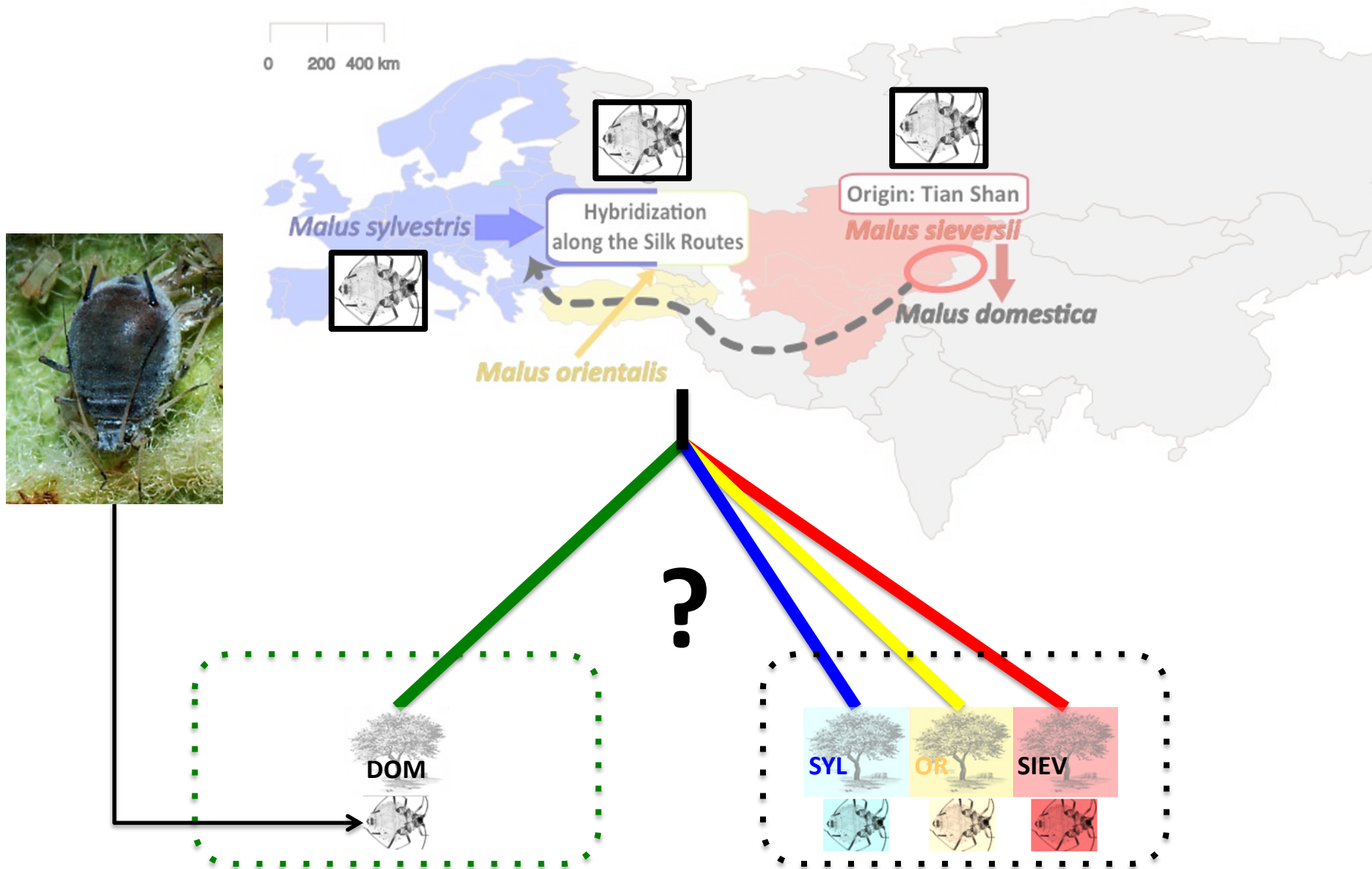




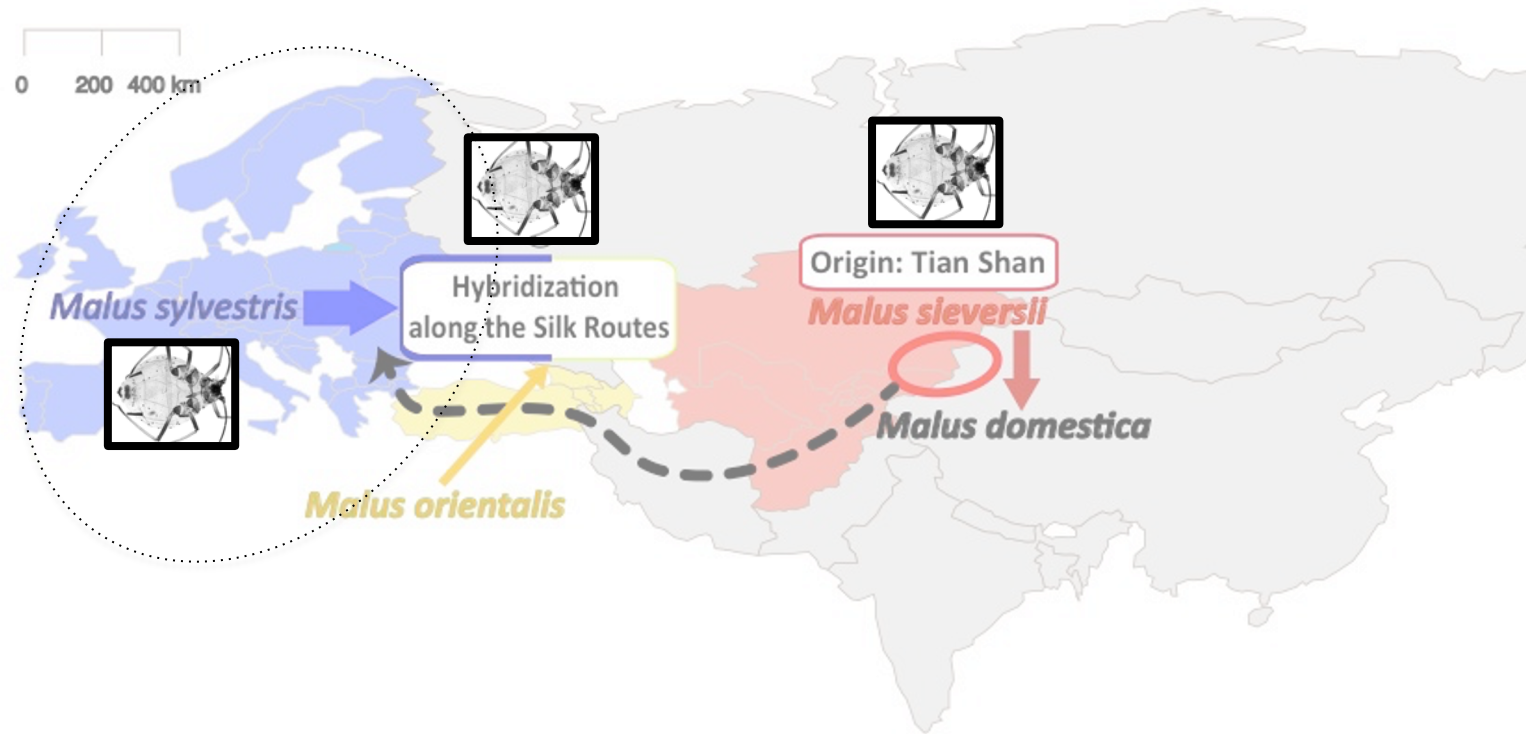
# The rosy apple aphid, *Dysaphis plantaginea*



# Aphid adaptive divergence during apple domestication?



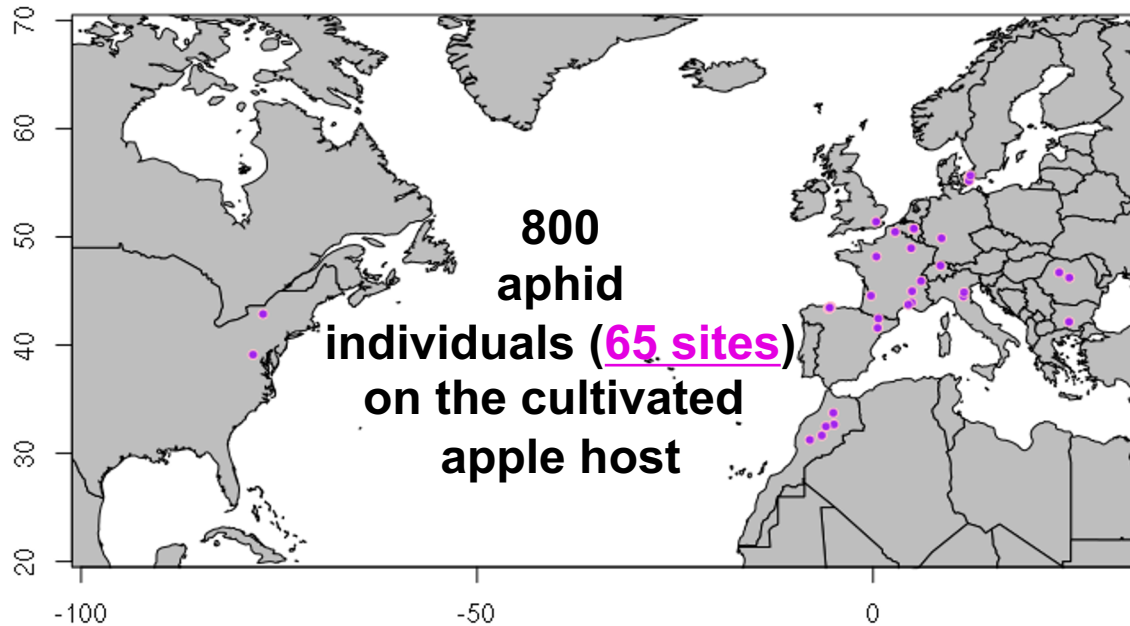
# Aphid adaptive divergence during apple domestication?



**Demographic history in Eurasia/Europe?**  
***De novo* genome of *Dysaphis plantaginea***  
**Diversity of endosymbiotic bacterial community?**



# Demographic history of the rosy apple aphid in Europe?



LabEx  
**BASC**  
Biodiversité, Agroécosystèmes,  
Société, Climat



anses  
Agence nationale de sécurité sanitaire  
alimentation, environnement, travail  
Connaître. Évaluer. Protéger.



Claire  
Mottet  
Benoît  
Barrès  
Elorri Segura

Myriam  
Harry



EVOLUTION  
CONSERVATION  
ÉCOLOGIE  
**EGCE**



Florence  
Mougél

écologie  
systématique  
évolution



Tatiana  
Giraud



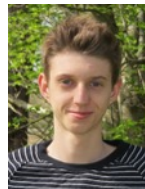
Agnès  
Rousselet



Matthieu  
Falque



Carine  
Remoué



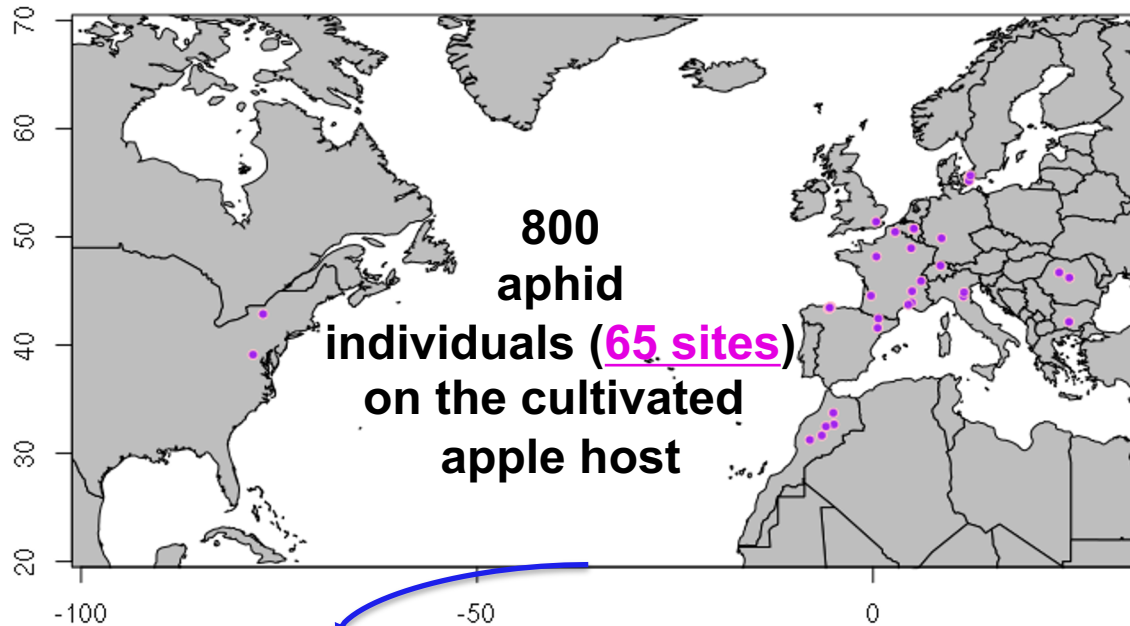
Anthony  
Venon



Harry  
Belcram

Génétique  
Quantitative  
et Évolution  
Le Moulin

# Demographic history of the rosy apple aphid in Europe?



LabEx  
**BASC**  
Biodiversité, Agroécosystèmes,  
Société, Climat



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systématique  
évolution



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Giraud



Agnès  
Rousselet



Matthieu  
Falque



Carine  
Remoué



Anthony  
Venon



Harry  
Belcram



Myriam  
Harry



ÉVOLUTION  
CONSTITUTIONNELLE  
ÉCOLOGIE  
**EGCE**



Florence  
Mougel

Development of 36 SSR  
markers



**Claire Benoit**  
**Mottet Barrès**  
**Elorri Segura**



**Tatiana  
Giraud**



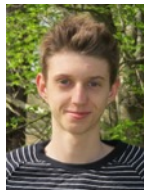
**Agnès  
Rousselet**



**Matthieu  
Falque**



**Carine  
Remoué**



**Anthony  
Venon**



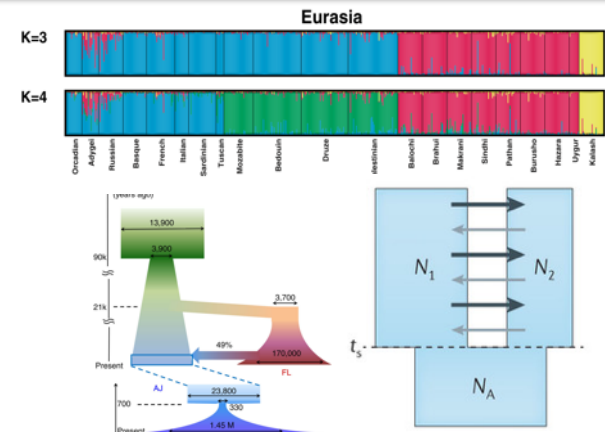
**Harry  
Belcram**



**Myriam  
Harry**



**Florence Mougel**

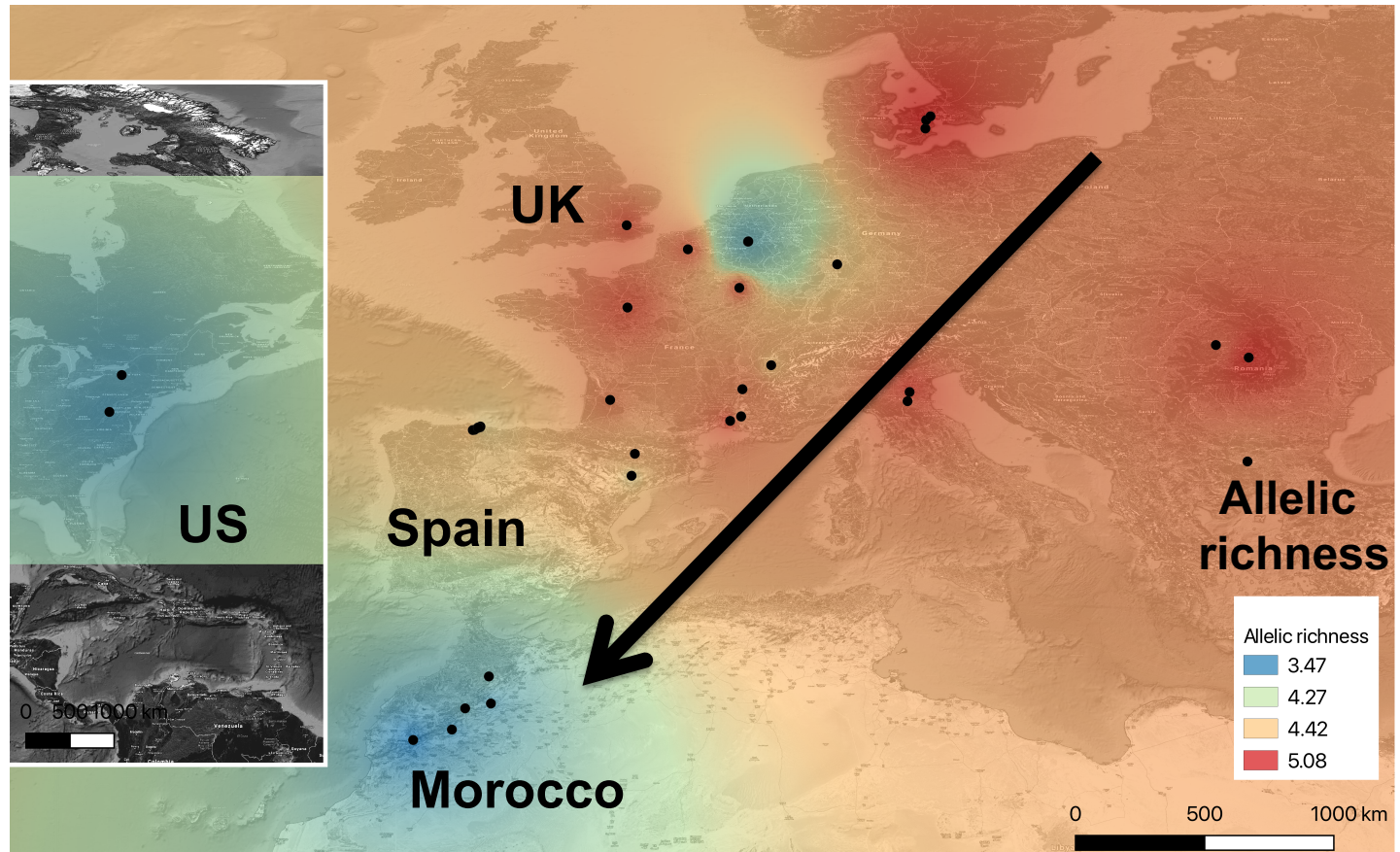




# A North-Southern gradient of genetic diversity : a recent colonization from Eastern Europe ?



**Sergio Vazquez**  
PhD candidate  
2019-2023

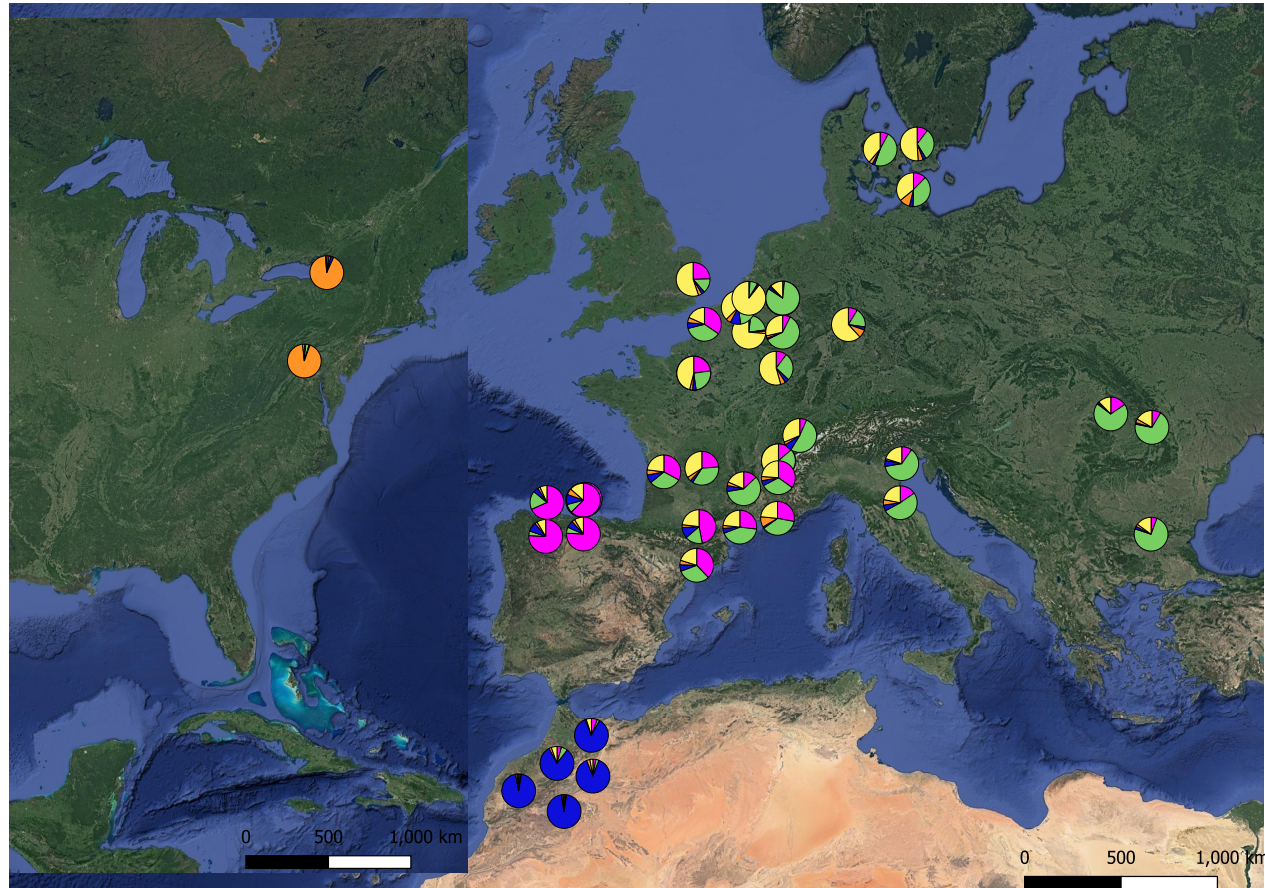




# Weak spatial genetic structure in Europe: Five genetic groups for *Dysaphis plantaginea*



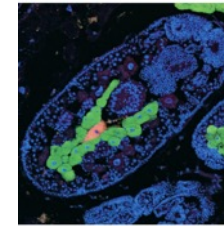
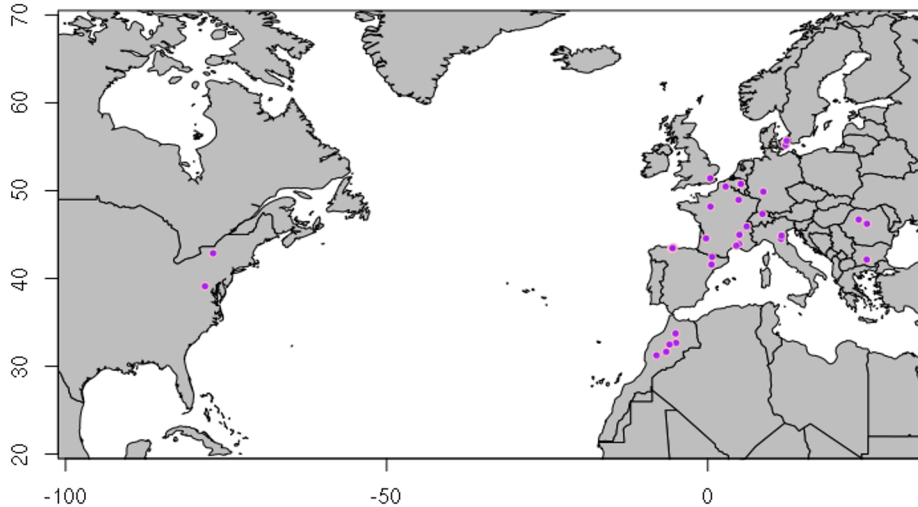
**Sergio Vazquez**  
PhD candidate  
2019-2023



Coalescent-based modeling:  
substantial gene flow during colonization

➡ Shaped by scions exchanges?

# Aphid adaptive divergence during apple domestication?



*Buchnera  
aphidicola*



*Dysaphis  
plantaginea*

## Metabarcoding 16s



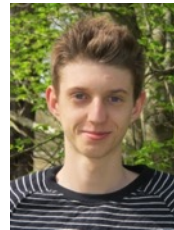
Ludwig  
Jardillier

Philippe  
Deschamps



Emmanuelle  
Jouselin

Maxime  
Galan



Anthony  
Venon

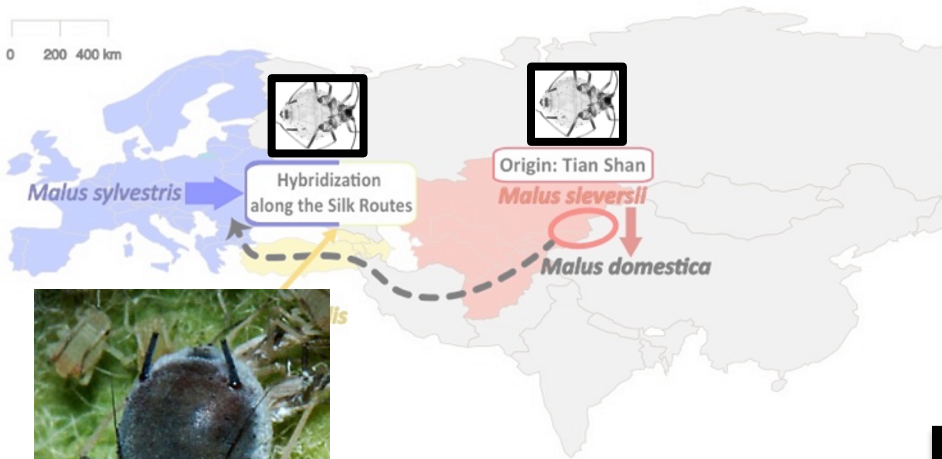
Laure  
Benoit

Surprisingly low diversity  
with only *Buchnera* across  
its distribution!



# Aphid adaptive divergence during apple domestication?

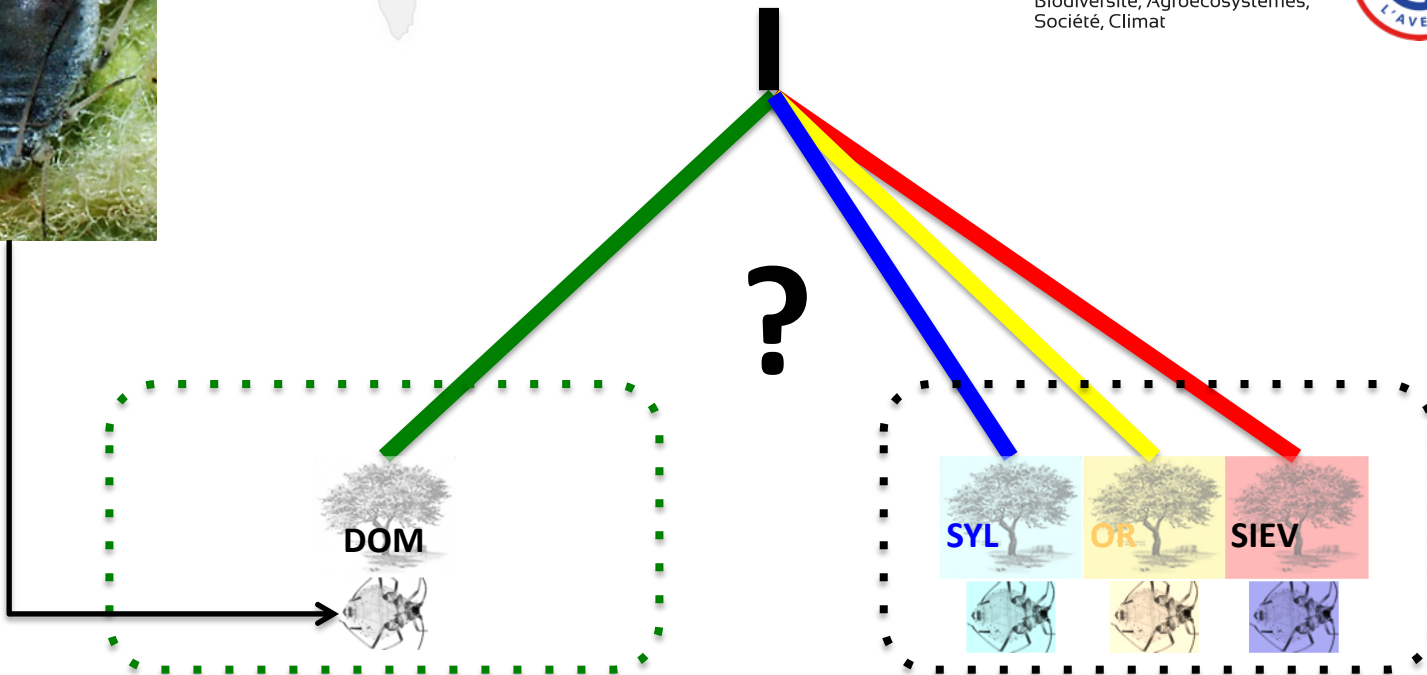
GENOMIC DATA!!!



What is the demographic history of the RAA in Eurasia? ✓

(SSR dataset)

LabEx  
**BASC**  
Biodiversité, Agroécosystèmes,  
Société, Climat



# Aphid adaptive divergence during apple domestication?

## ASSEMBLING A NEW REFERENCE GENOME OF *D. PLANTAGINEA*

« 10X » genomics –  
Chromium new technology + BioNano



2017, 2019



Assembly of the aphid genome:

-6 chromosomes

-400 Mb

-N50: 2Mb

+ Genomes of endosymbiotic bacteria



Myriam  
Harry



Jean-Christophe  
Simon



Johann  
Joets



Pierre  
Gérard



Harry  
Belcram



Fabrice  
Legeai



Dominique  
Lavenier



Claire  
Mottet



Benoit  
Barrès

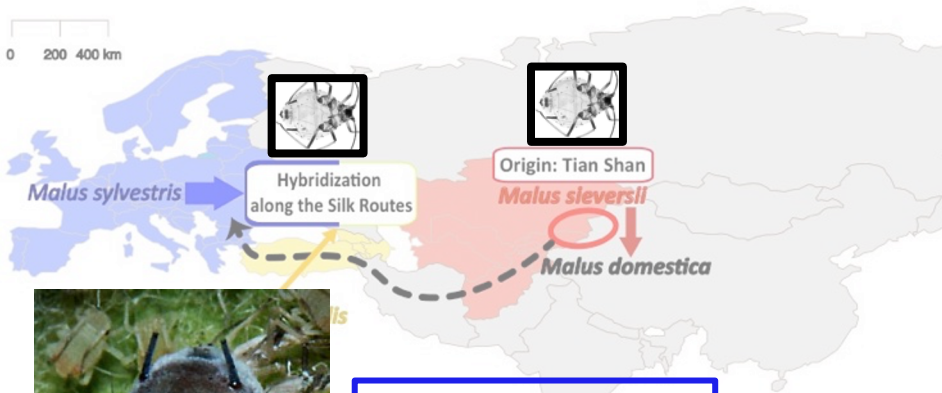


William  
Marande

Elorri Segura

# Aphid adaptive divergence during apple domestication?

GENOMIC DATA!!!



Local adaptive divergence in Europe?

ATIP  
avenir



What is the demographic history of the RAA in Eurasia?

(SSR dataset)

Genome *de novo*

?





2019-2021

# Aphid local adaptive divergence during apple domestication?

FITNESS

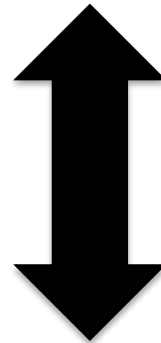
GENOME

EXPRESSION



*Dysaphis plantaginea*

The rosy apple aphid



The cultivated apple



*Malus domestica*

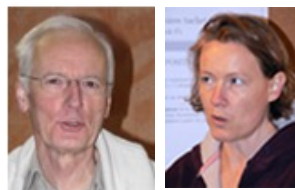


Climate

BIOTIC?

ABIOTIC?

# Thanks a lot for your attention



**Christine Dillmann**  
**Dominique de Vienne**  
**Nathalie Galic**  
**Adrienne Ressayre**



**Jérôme Enjalbert**  
**Isabelle Goldringer**



**Valérie Lespinas**  
**Elodie Chalard**  
**Rozenn Le Guyader**



**Olivier Martin**



**Philippe Brabant**



**Domenica Manicacii**



**Pierre Gérard**

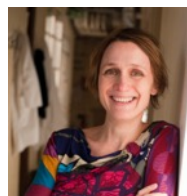
**Clémentine Vitte**



**Karine Alix**



**Martine Le Guilloux**



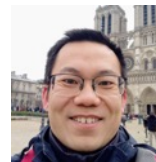
**Maud Tenailon**



**Agnès Rousselet**



**Johann Joets**



**Xilong Chen**



**Sergio Olvera Vasquez**

**Didier Tropée**

**Matthieu Falque**

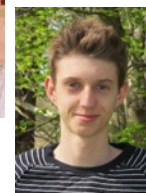


**Carine Remoué**



**Catherine Damerval**

**Anthony Venon**



**Hélène Corti**



**Aurélie Bourgaïs**

**Harry Belcram**



**Fabrice Dumas**



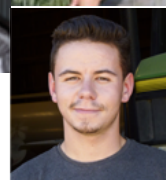
**Guillaume Lucas**  
**Lucas Rover**  
**Albert Kwarterg**



**Alain Charcosset**  
**Cyril Baudant**  
**Sophie Pin**  
**Valérie Combes**



**Jean-Pascal Meunier**



**William Eveno**

**Pierre Capy**  
**Jacqui Shykoff**



**Amandine Dubois**  
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