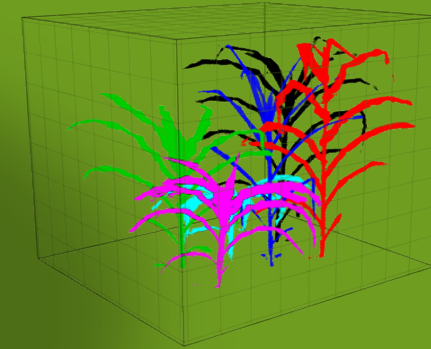
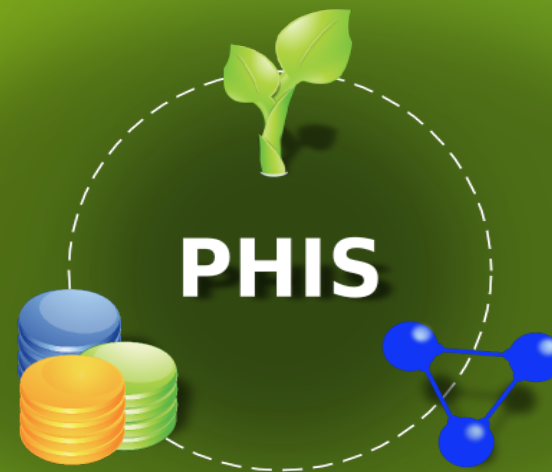


# Dealing with multi-source and multi-scale information in Plant Phenomics: the PHIS ontology-driven Information System



**Vincent Nègre**

**Llorenç Cabrera-Bosquet**

INRA-LEPSE Montpellier, France

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# Data Management Challenge

Plant phenomics is multi-source and multi-scale, with an added complexity of time

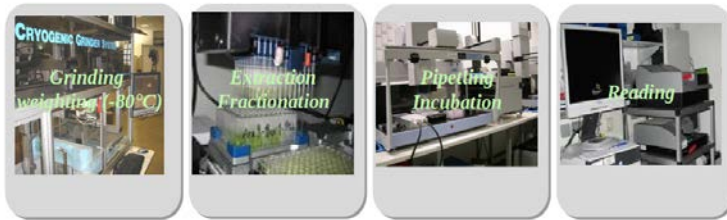
## « omics » Platforms

### Various data complex types

Genomics

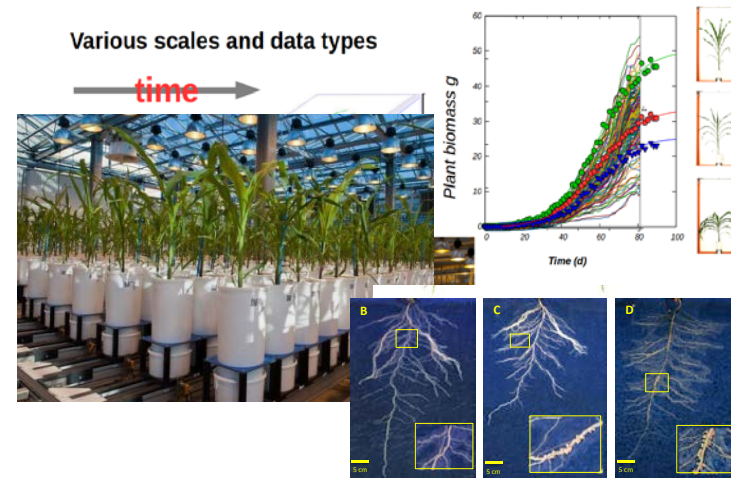
Composition and the structure of biopolymers

Quantification of metabolites and enzyme activities



## Green house Platforms

Various scales and data types



Managing all these data is a real challenge and probably one of the most limiting steps

## Field Platforms

Various scales and data types

- Cell, organ, plant, population
- Images, hyperspectral, spectral, sensors, human readings...



## Farm Platforms

Various scales and data types from thousands of farms

- organ, plant, population, site
- Images, sensors, human readings...

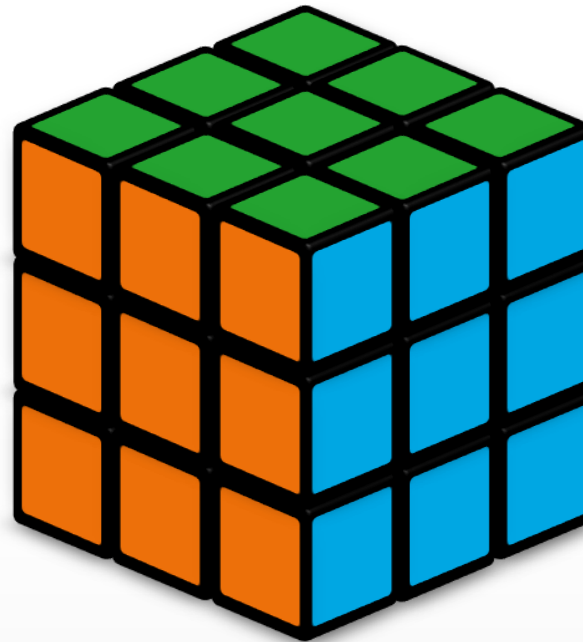


# PHIS is an Information System for plant phenomics able to... (Phenotyping Hybrid Information System)

## Data management

### Store, organise and manage

- Highly heterogeneous data (e.g. images, spectra, dynamic traits, environmental data)
- Multi-spatial and temporal scale data (leaf to canopy level)
- Multi-source (field, platform)



## Metadata enrichment

Not only storing data but...  
**Enrich datasets** with the necessary **knowledge** (enable reuse of data and meta-analyses)

[www.phis.inra.fr](http://www.phis.inra.fr)

## Methods

Dealing with multi-source and multi-scale information in plant phenomics: the ontology-driven Phenotyping Hybrid Information System

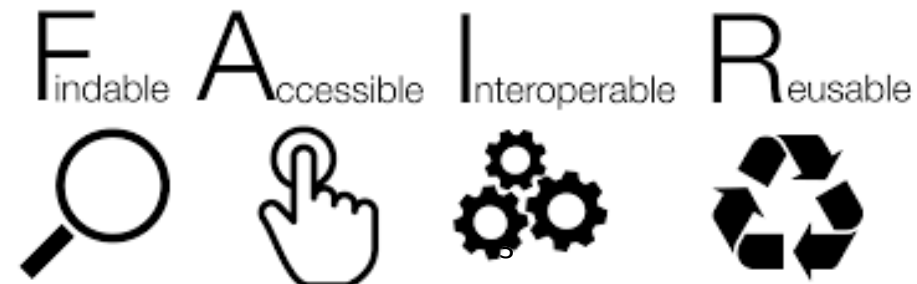
Pascal Neveu<sup>1</sup>, Anne Tireau<sup>1</sup>, Nadine Hilgert<sup>1</sup>, Vincent Nègre<sup>2</sup>, Jonathan Mineau-Cesari<sup>1,2</sup>, Nicolas Brichet<sup>2</sup>, Romain Chapuis<sup>3</sup>, Isabelle Sanchez<sup>1</sup>, Cyril Pommier<sup>4</sup>, Brigitte Charnomordic<sup>1</sup>, François Tardieu<sup>2</sup> and Llorenç Cabrera-Bosquet<sup>2</sup>

<sup>1</sup>MISTEA, INRA, Montpellier SupAgro, Université de Montpellier, Montpellier 34060, France; <sup>2</sup>LEPSE, INRA, Montpellier SupAgro, Université de Montpellier, Montpellier 34060, France; <sup>3</sup>UE DIASCOPE, INRA, Montpellier SupAgro, Université de Montpellier, Montpellier 34060, France; <sup>4</sup>INRA, UR1164 URGI – Research Unit in Genomics-Info, INRA de Versailles-Grignon, Route de Saint-Cyr, Versailles 78026, France

Neveu et al. *New Phytologist* 2019

## Interoperability

**Interoperate and integrate** data into/from external resources (e.g. modelling platforms or external databases)






# Object identification (URIs)

In PHIS all objects are identified using **URIs (Uniform Resource Identifiers)**

=> standardized, unique, unambiguous identification



**Prefix m3p:** <<http://phenome-fppn.fr/m3p>> (a)



**URI of plant**  
<m3p:arch/2017/c17000118>

**URI of pot:**  
<m3p:arch/2013/pc13001542>


**URI of cart:**  
<m3p:arch/2013/ct1300123>

**URI of cabin:**  
<m3p:arch/2018/ac180015>

**URI of camera:**  
<m3p:arch/2018/ac180019>

**URI of image:**  
<m3p:arch/2017/ic17002295855>

**Prefix diaphen:** <<http://phenome-fppn.fr/diaphen>> (b)



**URI of plot**  
<diaphen:2017/o1700029>

**URI of plant:**  
<diaphen:2017/17000147>

**URI of leaf:**  
<diaphen:2017/l17000590>

**URI of camera:**  
<diaphen:2018/ac180002>

**URI of image:**  
<diaphen:2017/ic14001480237>

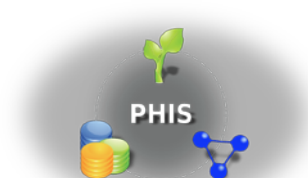
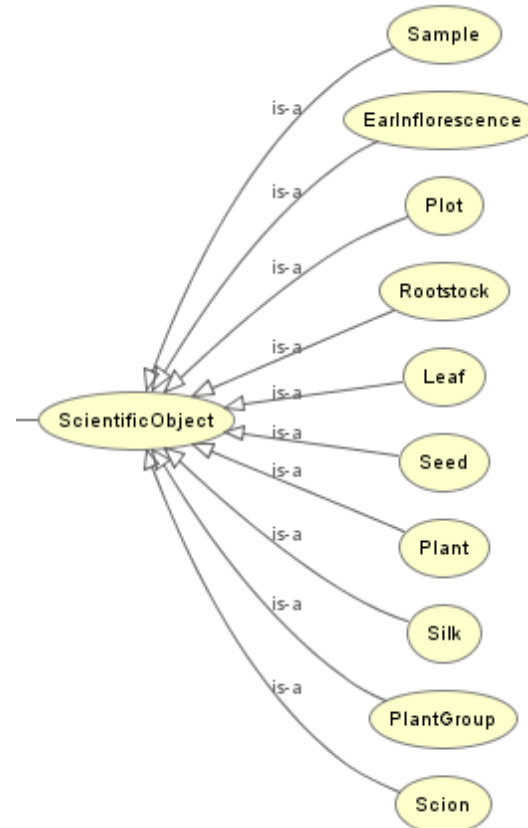
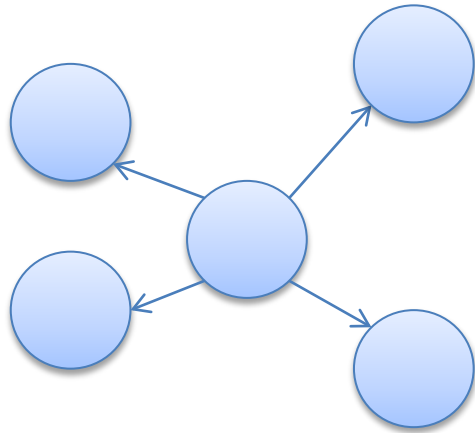
Neveu et al. *New Phyt* 2018

The same applies to sensors, people, events, infrastructure, variables...



# Ontologies

- Une **ontologie** est l'ensemble structuré des termes et concepts dans un domaine de connaissance.
- L'ontologie constitue en soi un modèle de données représentatif d'un ensemble de concepts, ainsi que des relations entre ces concepts.
- L'ontologie est aux données ce que la grammaire est au langage.



# How information is organised? Object identification and vocabulary (URIs and ontologies)

## Object identification

In PHIS all objects are identified using URIs  
(Uniform Resource Identifiers)  
=> standardized and unambiguous identification


**Prefix diaphen:** `<http://phenome-fppn.fr/diaphen>` (b)

**URI of plot**  
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**URI of leaf:**  
`<diaphen:2017/l17000590>`

**URI of camera:**  
`<diaphen:2018/ac180002>`



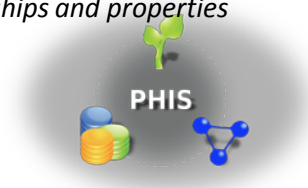
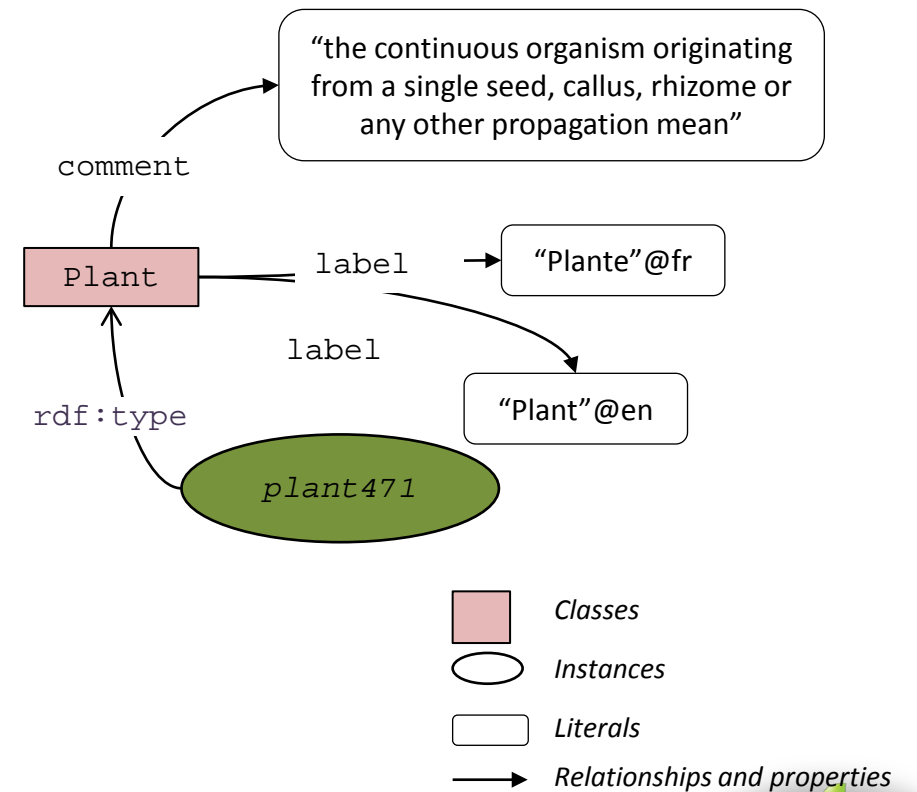
**URI of image:**  
`<diaphen:2017/ic14001480237>`

Neveu et al. *New Phyt* 2019

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## Semantics (controlled vocabulary)

Ontologies allow to define terms and formalise relationships between them



# How information is organised? Object identification and vocabulary (URIs and ontologies)

## Object identification

In PHIS all objects are identified using URIs (Uniform Resource Identifiers)  
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**Prefix diaphen:** `<http://phenome-fppn.fr/diaphen>` (b)


**URI of plot:**  
`<diaphen:2017/o1700029>`

**URI of plant:**  
`<diaphen:2017/17000147>`

**URI of leaf:**  
`<diaphen:2017/l17000590>`

**URI of camera:**  
`<diaphen:2018/ac180002>`

**URI of image:**  
`<diaphen:2017/ic14001480237>`

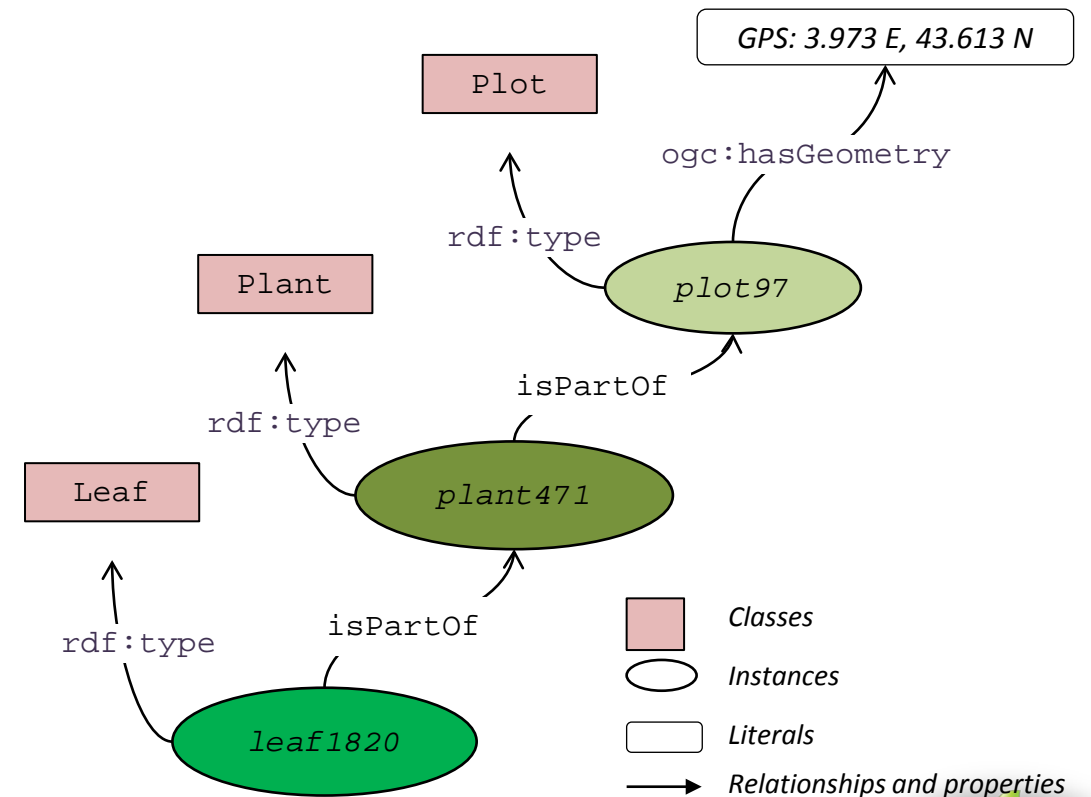


Neveu et al. *New Phyt* 2019

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## Semantics (controlled vocabulary)

Ontologies allow to define terms and formalise relationships between them

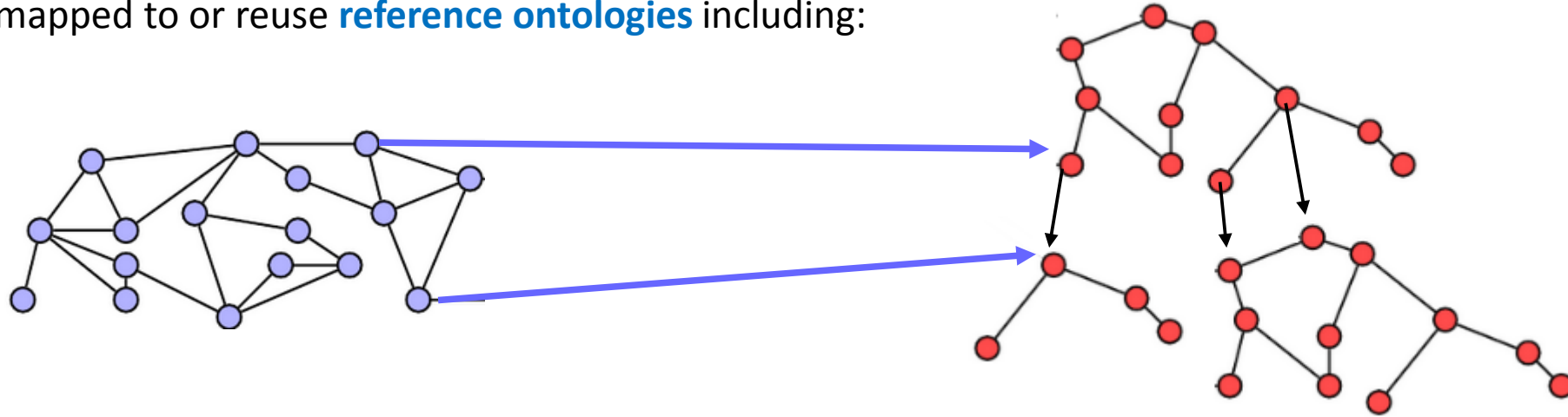


The same applies to sensors, people, events, infrastructure, variables...7



# Application vs reference ontologies

OEPO and OEEv **application ontologies** can be specific to either field or controlled conditions, but a number of terms and definitions are mapped to or reuse **reference ontologies** including:



## ***Application ontologies*** (cross domains of knowledge)

- **OEPO:** Ontology specialized for describing objects participating in phenotyping experiments
- **OEEv:** Ontology aimed to represent events that occur during an experiment

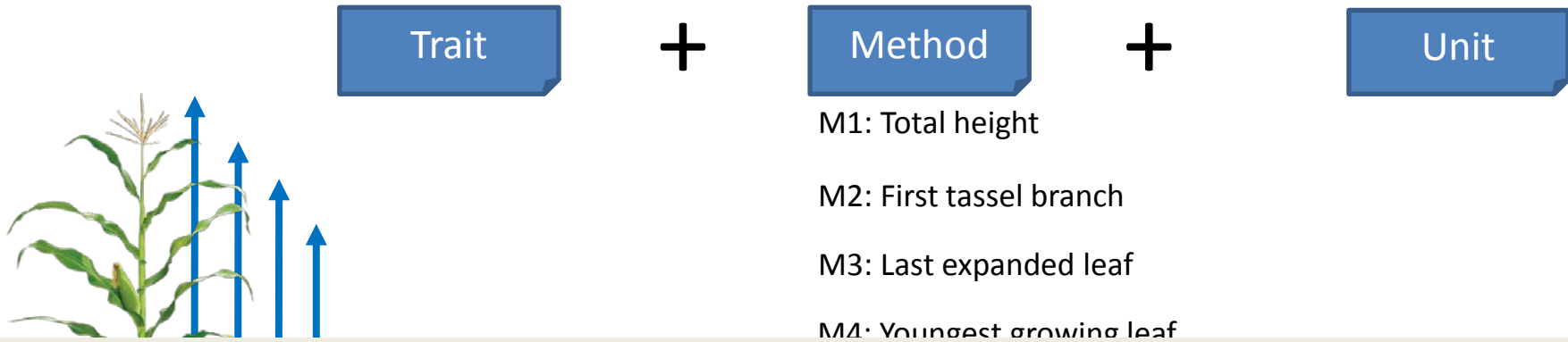
## ***Reference ontologies*** (domain specific)

- Crop ontology (CO)
- Plant Ontology (PO)
- FAO/Bioversity Multi Crop Passport Descriptors
- Semantic Sensor Network Ontology (SSN)
- PATO
- PPEO (MIAPPE)
- other semantic resources such as the AGROVOC, ICASA, EMPHASIS

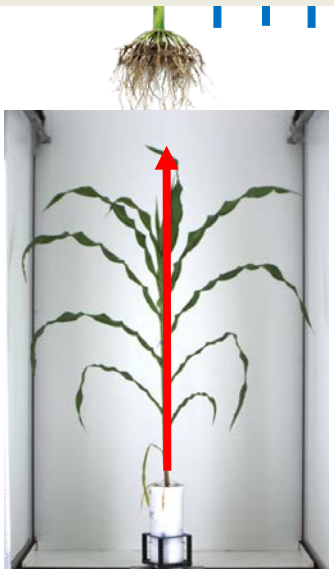


# Variable identification: Plant height example

In PHIS each measured variable is described using the *Trait + Method + Unit* structure



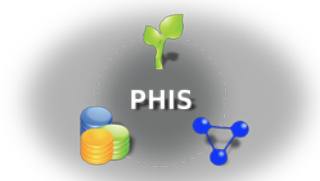
...There is an uncountable number of combinations...  
Each trait, method and unit has to be identified if we want to share and reuse data



T1: Plant Height

M5: Highest pixel corresponding to plant

U3: pixel



# A qui et à quoi sert PHIS?

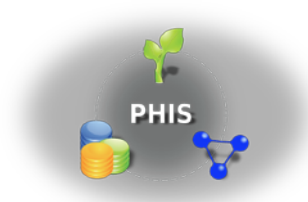
## 1. Platform users and staff

- Management of phenotyping experiments / infrastructure
- Data exploration and pre-analysis

## 2. External users (Interoperability with external platforms)

- Re-analysis and meta-analyses
- Modelling

## 3. Implementation into other platforms



# Experiments: contextual information

ARCH2017-03-30

Add annotation

Add event

QRCode

Graphic Visualization

Return to the list



Alias	ZA17
URI	<a href="http://www.phenome-fppn.fr/m3p/ARCH2017-03-30">http://www.phenome-fppn.fr/m3p/ARCH2017-03-30</a>
Species	Maize
Project	PHENOME-FPPN, Progress_Genetique, XYZ
Start	30 Mar 2017
End	30 Jun 2017
Installation(s)	<a href="http://www.phenome-fppn.fr/m3p/phenoarch">http://www.phenome-fppn.fr/m3p/phenoarch</a> , <a href="http://www.phenome-fppn.fr/m3p/phenodyn">http://www.phenome-fppn.fr/m3p/phenodyn</a>
Scientific Supervisor	<a href="mailto:Cabrera@supagro.inra.fr">Cabrera@supagro.inra.fr</a> , <a href="mailto:Francois.tardieu@supagro.inra.fr">Francois.tardieu@supagro.inra.fr</a> , <a href="mailto:Olivier.turc@supagro.inra.fr">Olivier.turc@supagro.inra.fr</a> , <a href="mailto:Welcker@supagro.inra.fr">Welcker@supagro.inra.fr</a>
Technical Supervisor	<a href="mailto:Nicolas.brichet@supagro.inra.fr">Nicolas.brichet@supagro.inra.fr</a> , <a href="mailto:Nathalie.luchaire@inra.fr">Nathalie.luchaire@inra.fr</a> , <a href="mailto:Benoit.suard@supagro.inra.fr">Benoit.suard@supagro.inra.fr</a>
Comment	<p>Cette manip vise à analyser les traits associés avec le progrès de rendement dans une série historique de maïs composée d'hybrides représentatifs des différents zones et leur réponse au déficit hydrique, en combinant des approches innovateurs basées sur le phénotypage à haut-débit en plateforme en complément avec des mesures au champ. Parmi les traits explorés: la variabilité de la croissance et la transpiration et leur réponse au déficit hydrique / haut température ainsi qu'un suivi sur le développement reproducteur via analyse d'image (caméra XYZ) et mesures fines. Le panel est composé de 60 hybrides français.</p> <p>Dans cette manip on a fait une pré-calibration de la manip sorgho qui aura lieu en septembre 2017.</p>
Keyword	Genetic gain, maize, grain abortion, silk growth, greenhouse, phenoarch
Document	<a href="#">Plme_d_17_00129.pdf</a>

Projects

Installations

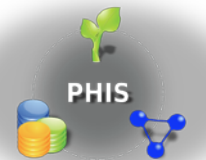
Staff & teams



Objects

#Object	349 Ear inflorescences, 359 Leaves, 1496 Plants
#Variety	62

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# Sensors and environmental variables

Sensor characteristics, linked events and outputs are easily visualized

par02\_p

[Add annotation](#)
[Add event](#)
[Return to the list](#)

Device Alias	par02_p
URI	<a href="http://www.phenome-fppn.fr/m3p/arch/2011/sa110008">http://www.phenome-fppn.fr/m3p/arch/2011/sa110008</a>
Device Type	RadiationSensor
Related Concept	<a href="http://purl.oclc.org/NET/ssnx/meteo/aws#QuantumSensor">http://purl.oclc.org/NET/ssnx/meteo/aws#QuantumSensor</a>
Brand	Skye Instruments
Model	SKP 215
Variable	PAR Light:weather station:micromole.m-2.s-1
Variable uri	<a href="m3p:/variable/ev000005">m3p:/variable/ev000005</a>
Documents	<a href="#">Par_quantum_skp215.pdf</a>

Data of par02\_p

Output

## Sensor characteristics

### Events linked

Showing 1-5 of 6 items.

#	Type	Description	Concern	Alias	Date of Event
1	oeev:Installation	PAR sensors placed at 210 cm above canopy	<a href="m3p:/arch/2011/sa110008">m3p:/arch/2011/sa110008</a>	par02_p	2017-05-17T12:00:00
2	oeev:Installation	PAR sensors placed at 180 cm above canopy	<a href="m3p:/arch/2011/sa110008">m3p:/arch/2011/sa110008</a>	par02_p	2017-05-09T12:00:00+01:00
3	oeev:Installation	PAR sensors placed at 160 cm above canopy	<a href="m3p:/arch/2011/sa110008">m3p:/arch/2011/sa110008</a>	par02_p	2017-05-04T12:00:00+01:00
4	oeev:Installation	PAR sensors placed at 140 cm above canopy	<a href="m3p:/arch/2011/sa110008">m3p:/arch/2011/sa110008</a>	par02_p	2017-04-28T12:00:00+01:00
5	oeev:ManualCalibration	Calibration	<a href="m3p:/arch/2011/sa110008">m3p:/arch/2011/sa110008</a>	par02_p	2017-03-13T12:00:00+01:00

Events linked

View / Download

SKP 215 PAR Quantum Sensor

Skye Instruments have been specialising in light and radiation sensors since 1983. All are designed, manufactured and calibrated to the highest standards. Each is supplied with a Calibration Certificate traceable to the UK's National Physical Laboratory (NPL). There are three PAR sensors in the range, PAR Quantum, PAR Special and PAR Energy models. All measure the Photosynthetically Active Radiation between 400-700 nm, the part of the solar spectrum used by plants for photosynthesis and sugar production.

The most popular is the PAR Quantum sensor which is used to measure photon irradiance, or quantity of PAR light. It is calibrated in units of  $\mu\text{mol m}^{-2}\text{s}^{-1}$  (number or quanta of photons). Sensors are suitable for use in natural solar radiation or any lamp or light source. Each is fully waterproof and guaranteed submersible to 4m depth. Indoor versions are also available, please ask for details of sensors for environmental control.

As with all Skye sensors, the PAR Quantum sensor has been quoted in many scientific references, please ask for a list of publications. They are compatible with Skye Display Meters, SpectroSense2 meters and DataLog2 loggers. A choice of outputs are also available to suit most dataloggers and controllers.

Linked documents





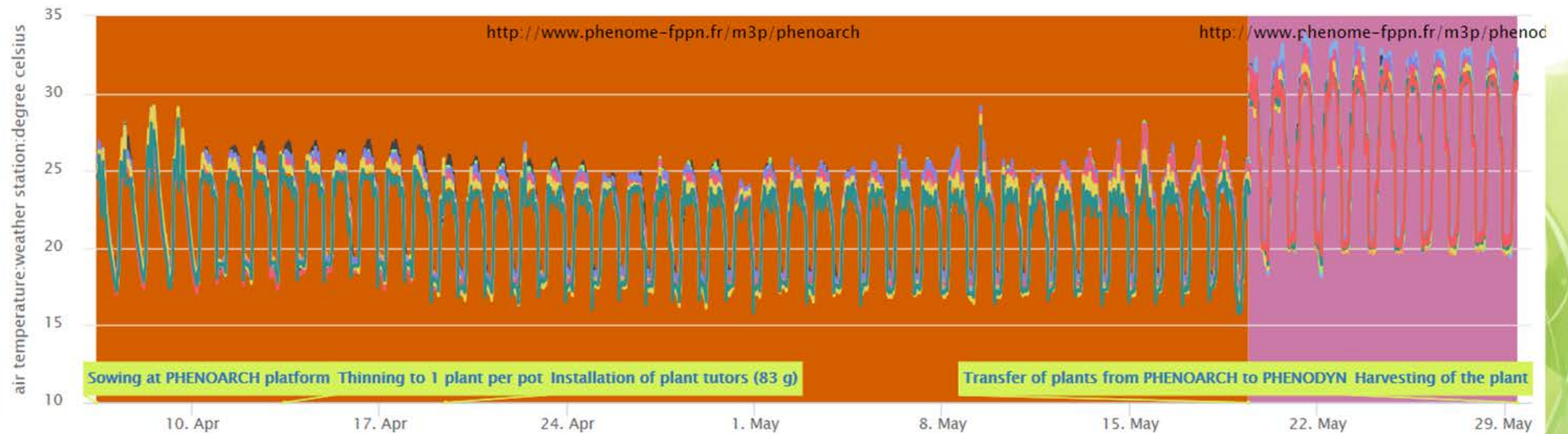
<http://www.phenome-fppn.fr/m3p/arch/2017/c17000241>

Code Variable

air temperature:weather station:degree celsius

Show

Data of air temperature:weather station:degree celsius



# Graphic visualisation

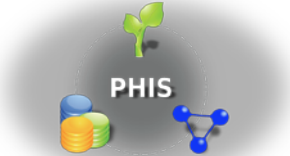
- Display of images, and time courses of phenotypic and environmental variables
- Raw images, segmented images and metadata can be displayed in both field and greenhouse experiments
- The interaction with the knowledge linking data with events and environmental sensor outputs.

The screenshot shows the 'Phenotyping Hybrid Information System' interface. On the left, there are search criteria for 'Experiment (ex. ARCH2016-04-15)', 'Object Type' (Ear inflorescence), 'Variety (ex. Lo1270\_H)' (iPG029), and 'Scientific Objects'. Below these are 'Variables Selection' options for 'Imaging (ex. Convex Hull Plant Area)', 'View Type (ex. side60)', and 'Phenotyping'. The main area displays a time-course graph of 'Total plant height' from June 1, 2017, to June 10, 2017. A pop-up window 'Add annotation or event' is overlaid on the graph, with options for 'Add Event' and 'Add annotation'. A small inset image (c) shows a close-up of a corn ear.

Panel (d) shows 'Image Visualization' of a plant. It includes a QR code, a date (2017-07-08 08:00), a provider (Naxos), a view type (side60), and a full URL. Below the text are two circular images: the left one shows a green plant, and the right one shows a red plant.

Panel (e) shows 'Image Visualization' of a plant in a greenhouse. It features two images: a green plant on the left and a red plant on the right, both in pots.

Panel (f) shows a heatmap of a field with a color scale for 'Total plant height' ranging from 150 (purple) to 300 (orange). A tooltip for a specific genotype is shown: 'genotype: iPG138, plotid: 167, scenario-rep: WD1-1'. A legend at the bottom right identifies the color scale.



# A qui et à quoi sert PHIS?

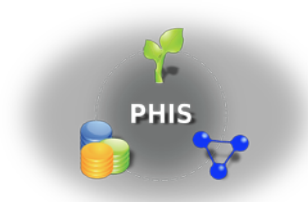
## 1. Platform users and staff

- Management of phenotyping experiments / infrastructure
- Data exploration and pre-analysis

## 2. External users (Interoperability with external platforms)

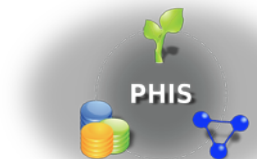
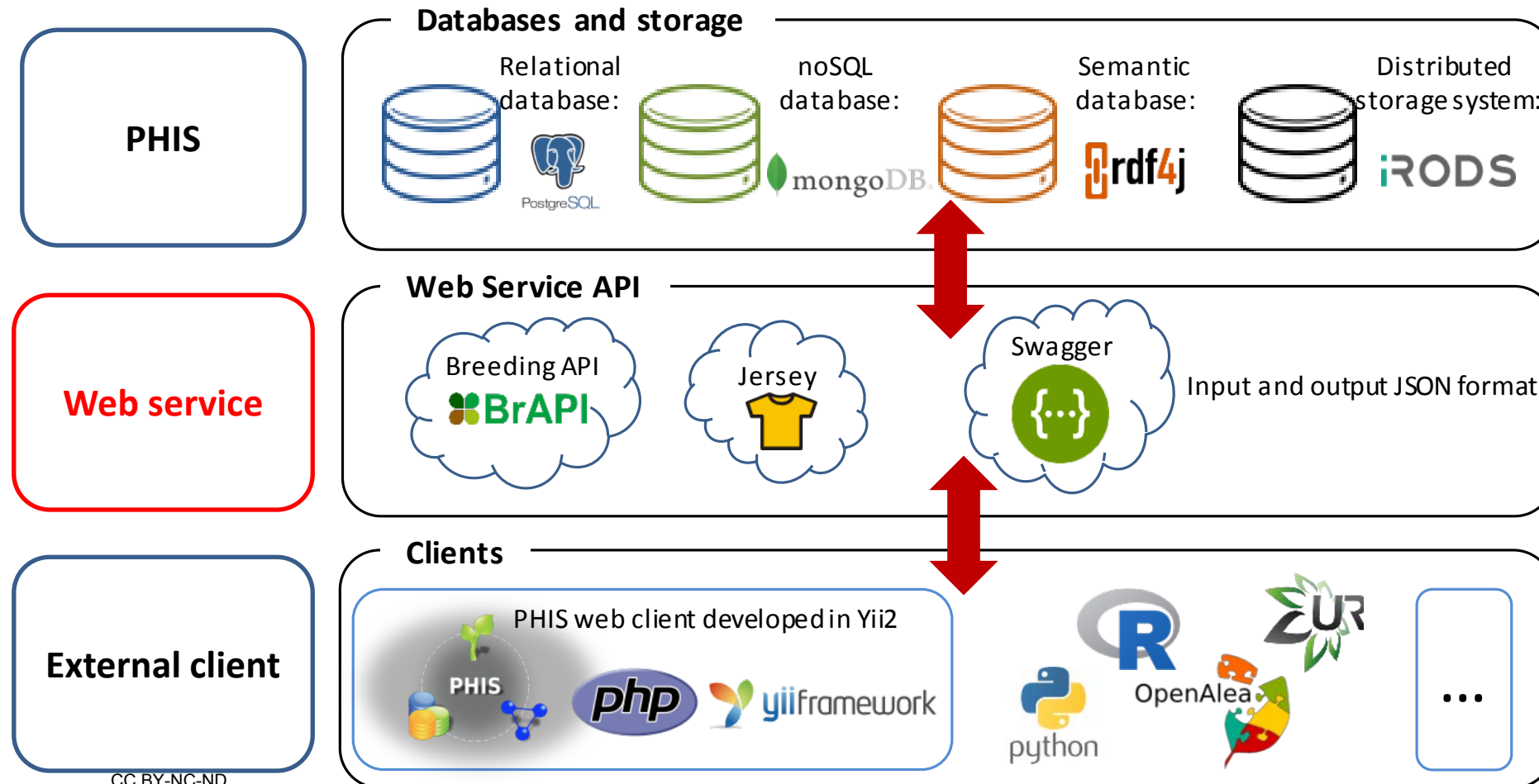
- Re-analysis and meta-analyses
- Modelling

## 3. Implementation into other platforms



# Web service API

**Web service** API allows one to virtually interoperate with any external client

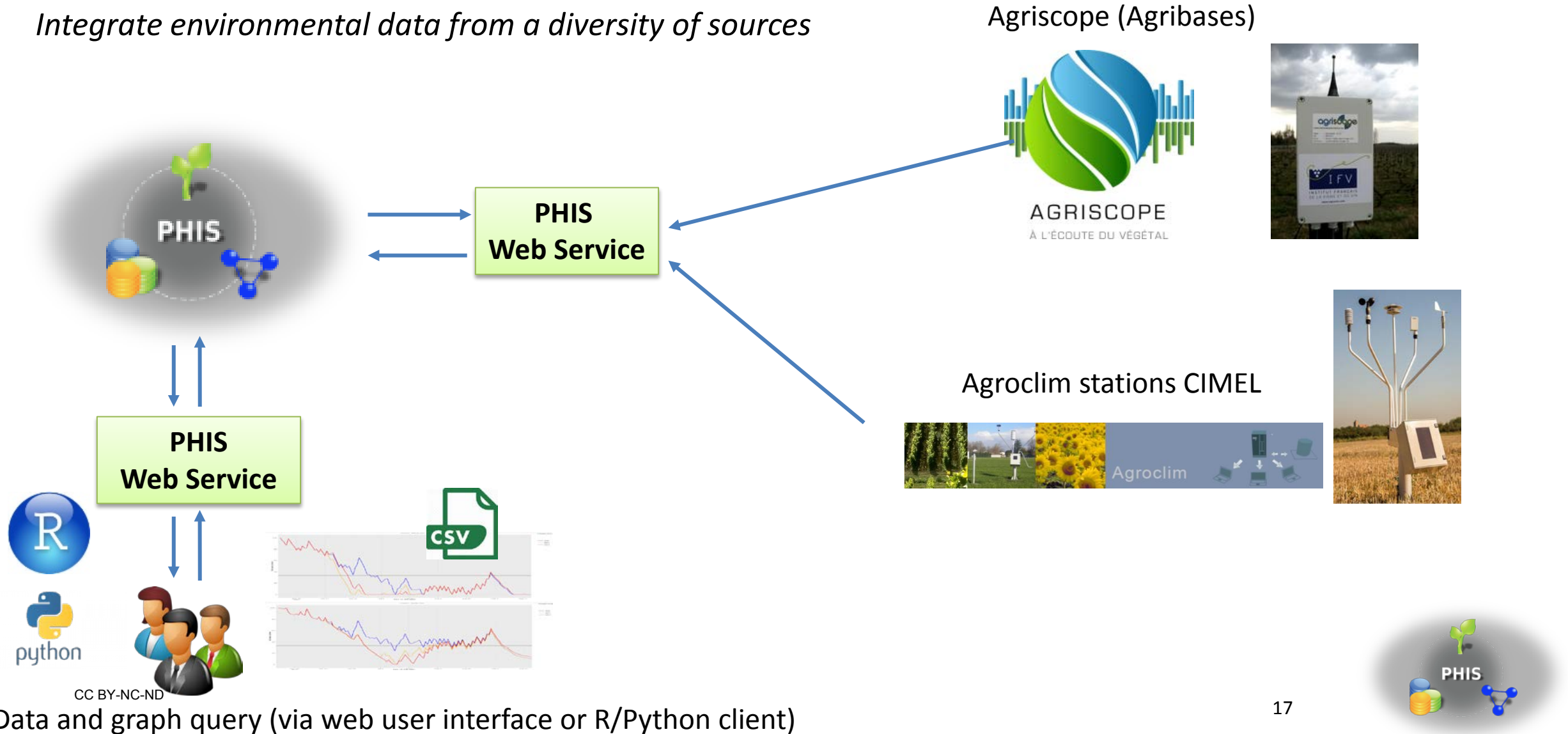




# Interoperability with external DBs and resources

Web services allow to virtually integrate and import data to any external client

*Integrate environmental data from a diversity of sources*



# Interoperability: 3D reconstruction pipeline

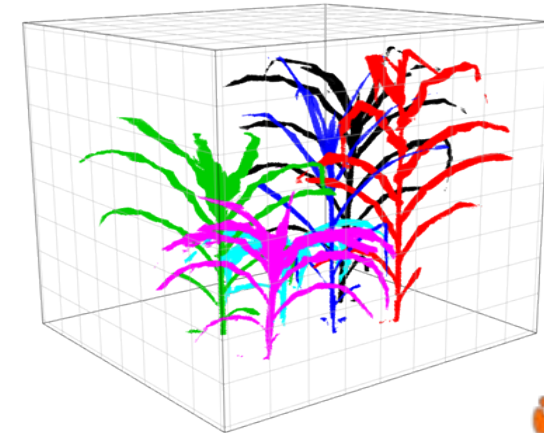
PHIS may provide data and contextual information necessary to perform image analysis and re-analysis of datasets



- Images
- Camera settings
- Events
- Camera Calibration



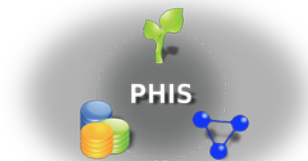
**PHIS  
Web Service**



**Phenomenal Pipeline  
(3D reconstruction)**



Artzet *et al.* in prep



# A qui et à quoi sert PHIS?

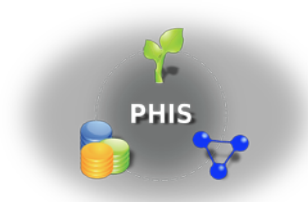
## 1. Platform users and staff

- Management of phenotyping experiments / infrastructure
- Data analysis

## 2. External users (Interoperability with external platforms)

- Integration of external data
- Re-analysis and meta-analyses
- Genetic and Modelling platforms

## 3. Implementation into other platforms

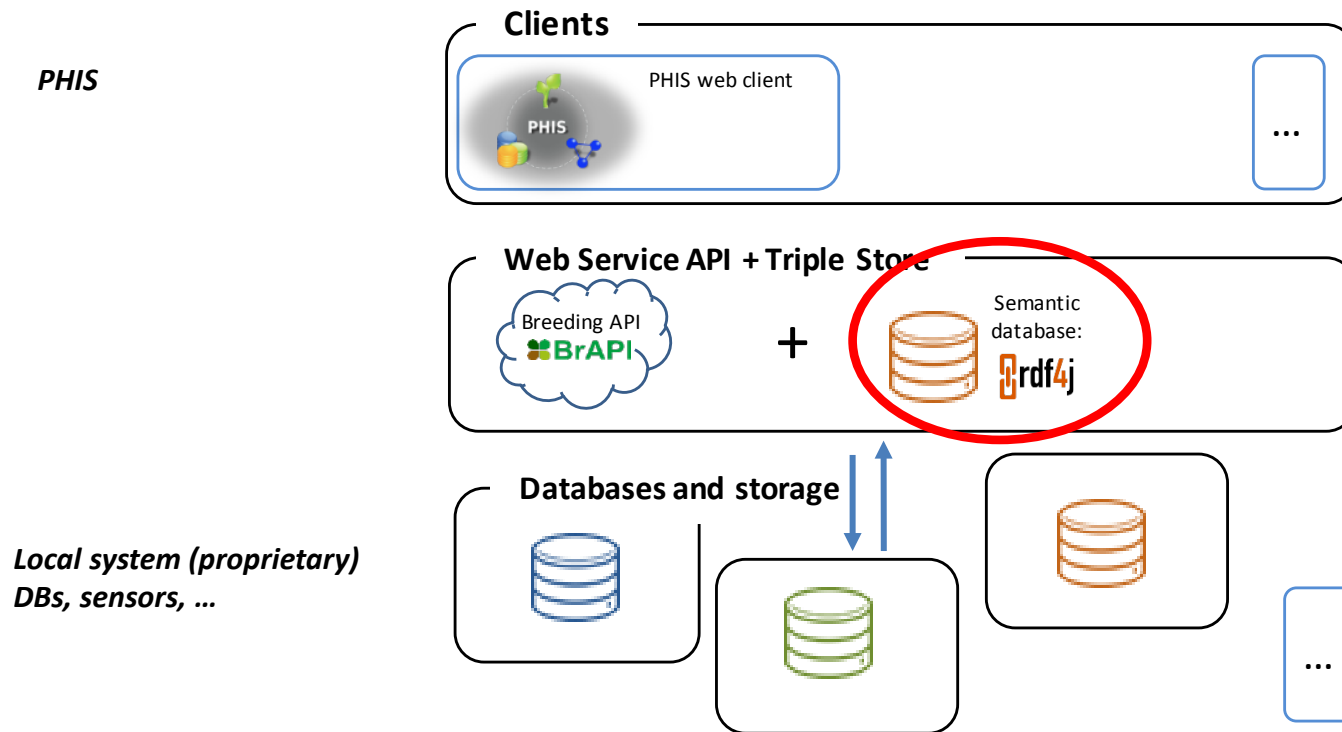


# Implementation into other platforms ?

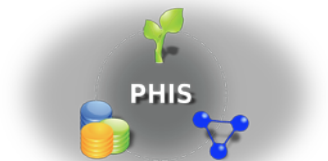
Can PHIS be implemented in other installations?

## Ontology adaptation

### Interoperability with local DBs



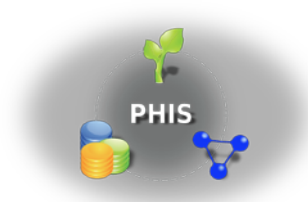
PHIS is being installed in other installations (5 PHENOME nodes, University of Nottingham and WUR)



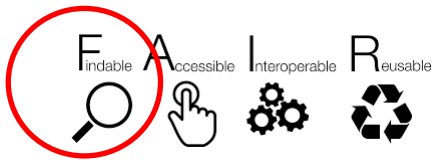
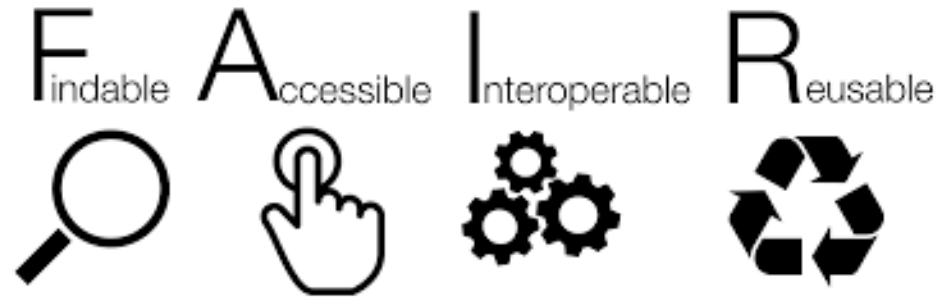


## Why PHIS?

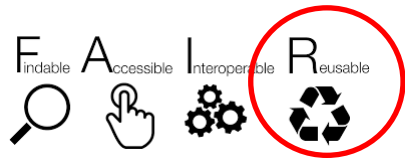
- Allows integration, management and visualisation of multi-source and multi-scale data
- Analysis and meta-analyses
- Integration of external data
- Flexible design => adaptability to other installations



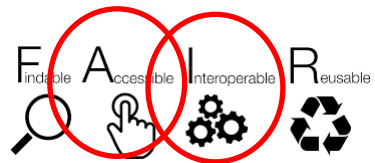
# TAKE HOME MESSAGES



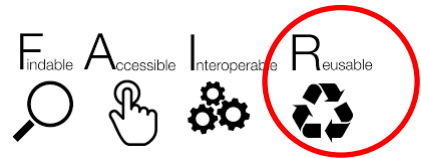
- International identification (**URI**)



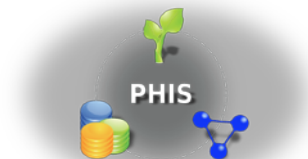
- Semantics (**Ontologies**, standardized vocabularies)



- Portal interoperability (**Web services**) with external resources

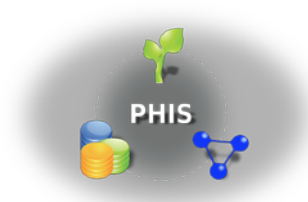


- **Tracability** (eg. Events) and reproducibility



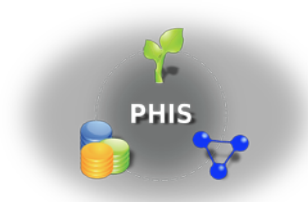
## Skills needed:

- System administrator (software installation)
- Data scientist (data management, development of data pipeline and data analysis tools )
- Scientific knowledge (ontologies development)



## Skills needed:

- System administrator (software installation)
- Data scientist (data management, development of data pipeline and data analysis tools )
- Scientific knowledge (ontologies development)





# Acknowledgements

## MISTEA

Pascal Neveu  
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## LEPSE

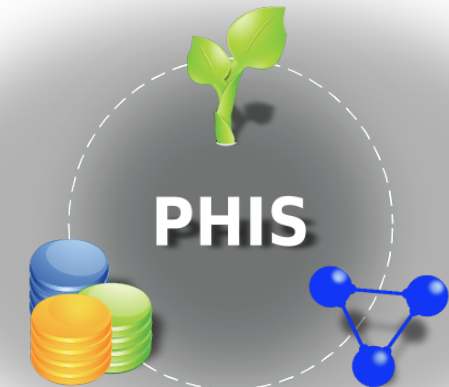
François Tardieu  
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Vincent Nègre  
Jonathan Mineau-Cesari  
Nicolas Brichet



## PHENOME partners

Patrick Moreau  
Cyril Pommier  
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A photograph of several green corn plants growing in a greenhouse. The plants are in the foreground, with their long, pointed leaves and developing ears visible. The background is filled with more plants and rows of warm, yellowish lights hanging from the ceiling, creating a soft, blurred effect. The overall scene is bright and vibrant, suggesting a healthy indoor growing environment.

**Thanks for your attention!**