The Plant Ontology
A Resource for Plant Genomics

Plant Ontology Consortium Members and Curators*:

Laurel D. Cooper*, Justin Elser, Justin Preece and Pankaj Jaiswal*:
   Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR

Ramona L. Walls* and Dennis W. Stevenson: The New York Botanical Garden, Bronx, NY

Maria A. Gandolfo: Department of Plant Biology, Cornell University, Ithaca, NY

Ontology Consultants:

Chris Mungall: Gene Ontology, Lawrence Berkeley National Lab, Berkeley, CA

Barry Smith: OBO Foundry, Department of Philosophy, University at Buffalo, NY

www.plantontology.org

The Plant Ontology is…

…a controlled vocabulary

☐ **all : all [46545]** 🌐
  ☐ ⓘ **PO:0025131 : plant anatomical entity [46280]** 🌐
    ⊞ ⓘ PO:0025117 : plant anatomical space [4]
    ⊞ ⓘ PO:0009011 : plant structure [46280]
    ⊞ ⓘ PO:0025161 : portion of plant substance [2]
  ☐ ⓘ **PO:0009012 : plant growth and development stage [38493]** 🌐
    ⊞ ⓘ PO:0007021 : plant structure development stage [20900]
    ⊞ ⓘ PO:0007033 : whole plant growth stage [36739]

- two aspects

- terms cover the plant domain

Each term has:

- primary name and synonyms

- unique PO ID and url

- definition vetted by experts, with community feedback

plant anatomical entity

| Term information ⬇ | Term lineage ⬇ | External references ⬇ | Term annotations ➡ |

Term Information

Accession	PO:0025131
Ontology	plant anatomy
Synonyms	None
Definition	An anatomical entity that is or was part of a plant. [source: CARO:0000000, POC:curators]
Comment	Includes both material entities such as plant structures and immaterial entities such as plant anatomical spaces. CARO:0000000 anatomical entity is defined as: Biological entity that is either an individual member of a biological species or constitutes the structural organization of an individual member of a biological species.

The Plant Ontology is…
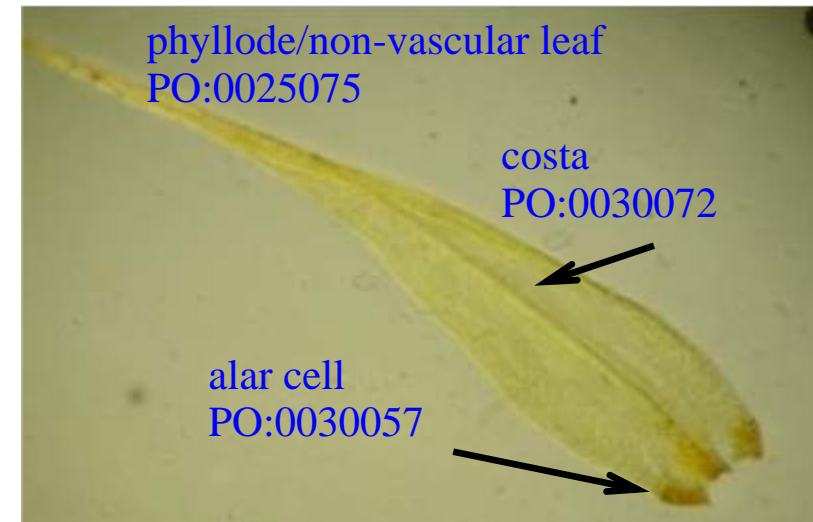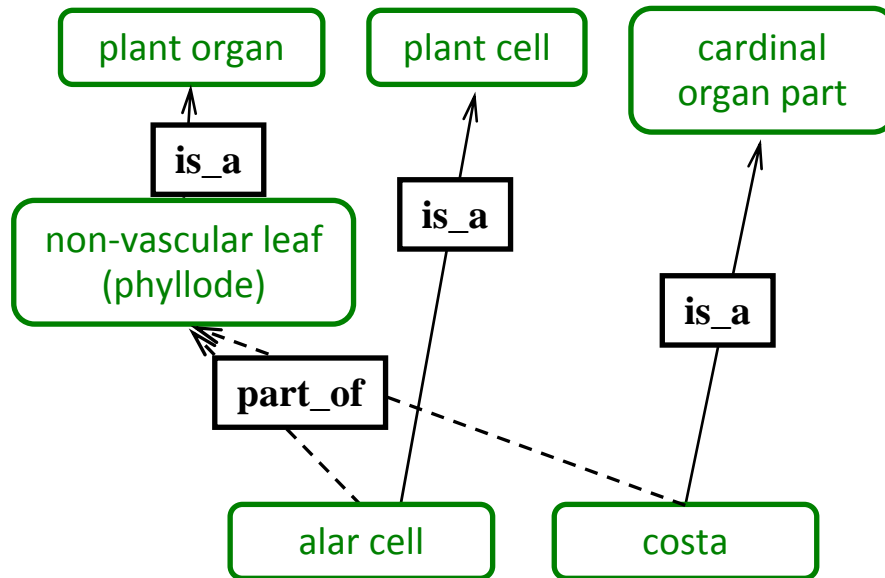
…a tool for reasoning across large data sets

Image: Aisling T. Walsh

Relations among terms allow for reasoning: "Find me all the genes expressed in a phyllode."

Vision and Goals of the Plant Ontology:

- **Encompass <u>all</u> plants** : including gymnosperms, lycopods, ferns and bryophytes

- **Facilitate comparative genomics** across taxa by linking descriptions to genomics datasets

- **Create mappings (links)** to other ontologies such as the Gene Ontology, CARO and PATO

- **Follow OBO Foundry principles:** openness, format, delimited content, collaborative, etc

Challenges in expanding the Plant Ontology to cover all plants:

Diversity in anatomy, morphology, life cycles, growth patterns
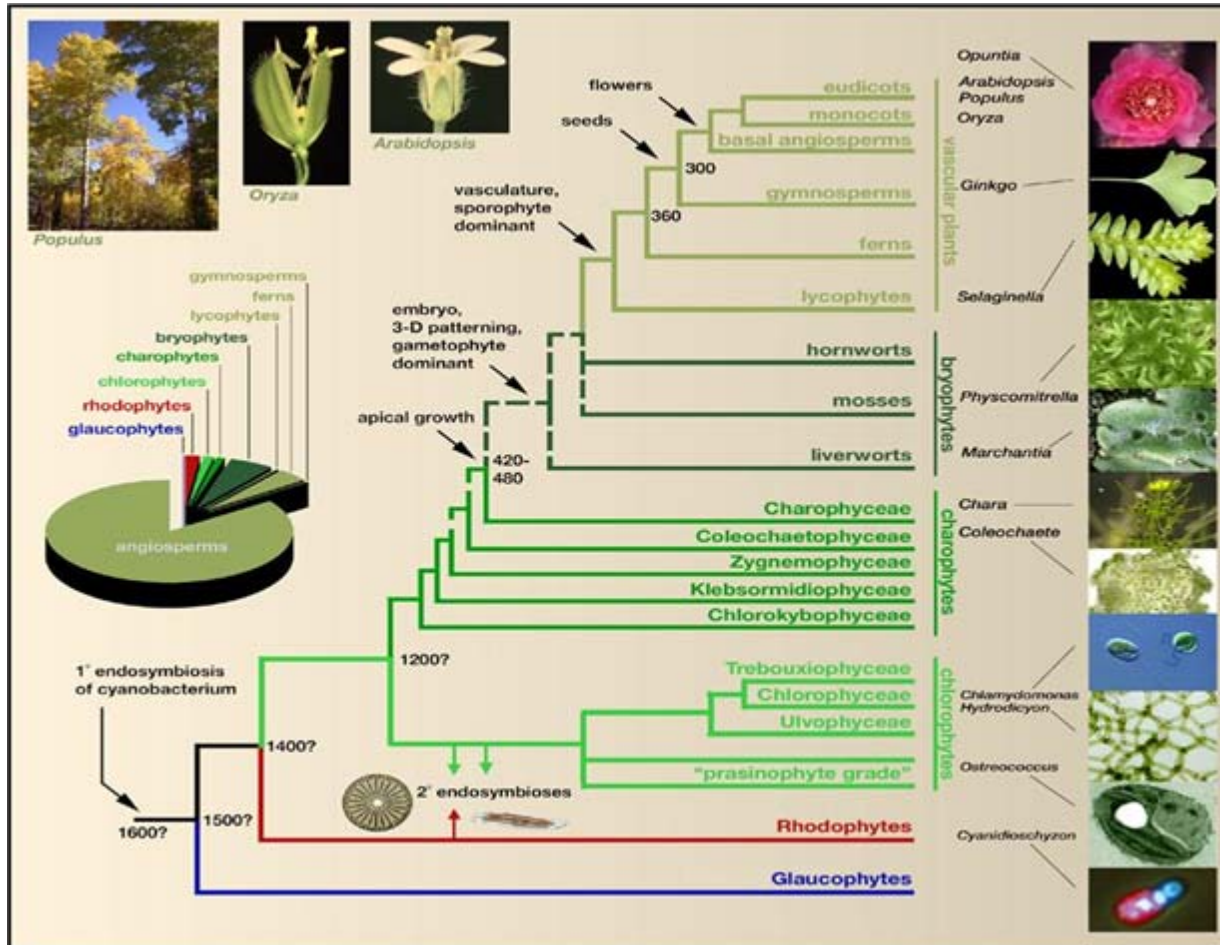
Seed plants
(Angiosperms and Gymnosperms)

Pteridophytes
(Ferns and Lycopods)

Bryophytes
(Mosses, Hornworts and Liverworts)

Algae

Bowman et al, Cell, 2007

Phylogenetic diversity can result in inconsistency in nomenclature:

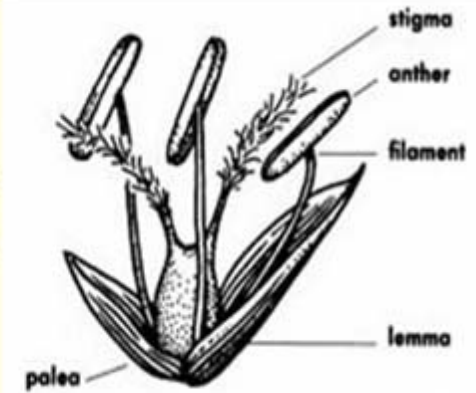**Instances of leaf: (PO:0025034)**

maple leaf   pine needle

palm frond

Different names are used for the same structure
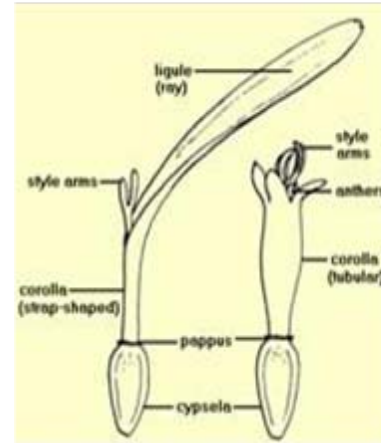
Asteraceae   Poaceae

Different structures can have the same name e.g. 'floret'

The PO provides consistent terminology for annotation of plant structures and growth and developmental stages across taxa

# Recent changes to the PO:

Two branches or subdomains of the PO are now merged:

Plant Anatomy

PO:0025131 : plant anatomical entity [46280]
- PO:0025117 : plant anatomical space [4]
- PO:0009011 : plant structure [46280]
- PO:0025161 : portion of plant substance [2]

Plant Structure Development Stage (beta)

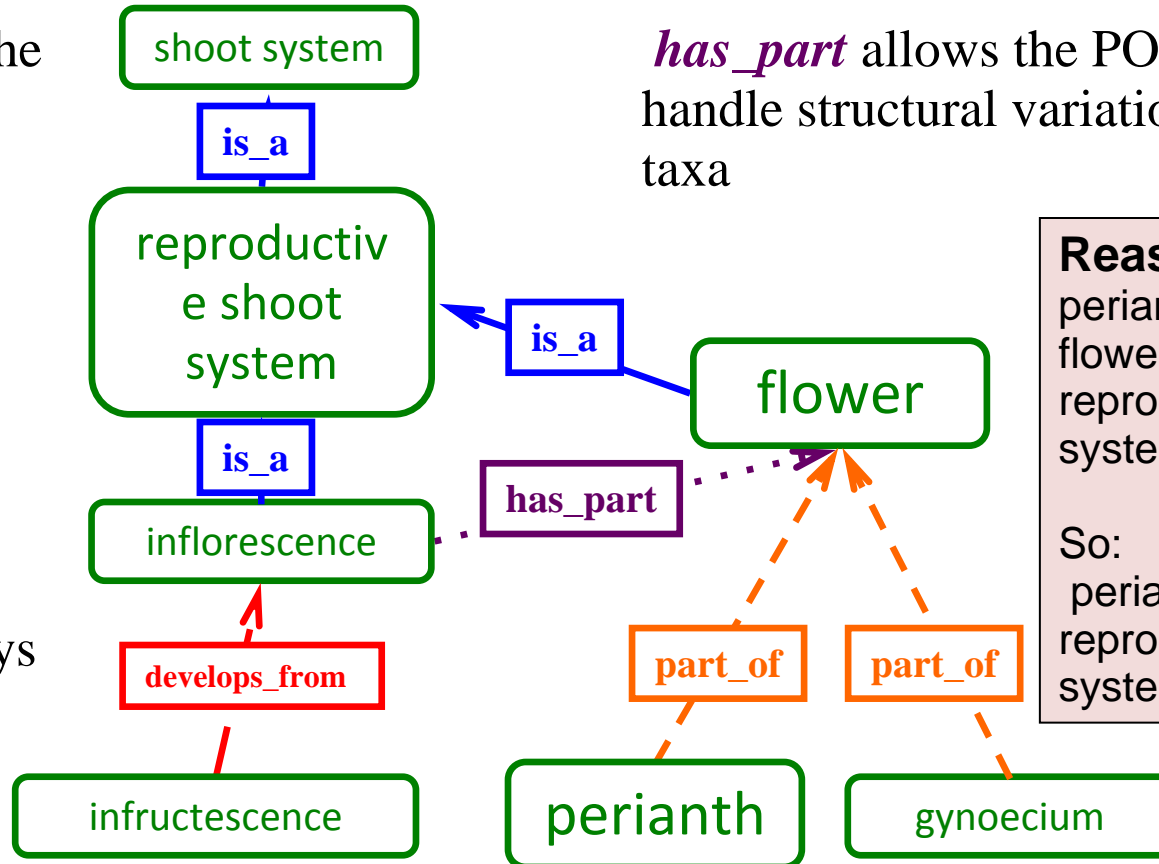PO:0009012 : plant growth and development stage [38493]
- PO:0007021 : plant structure development stage [20900]
- PO:0007033 : whole plant growth stage [36739]

Organization of Plant Anatomy Branch
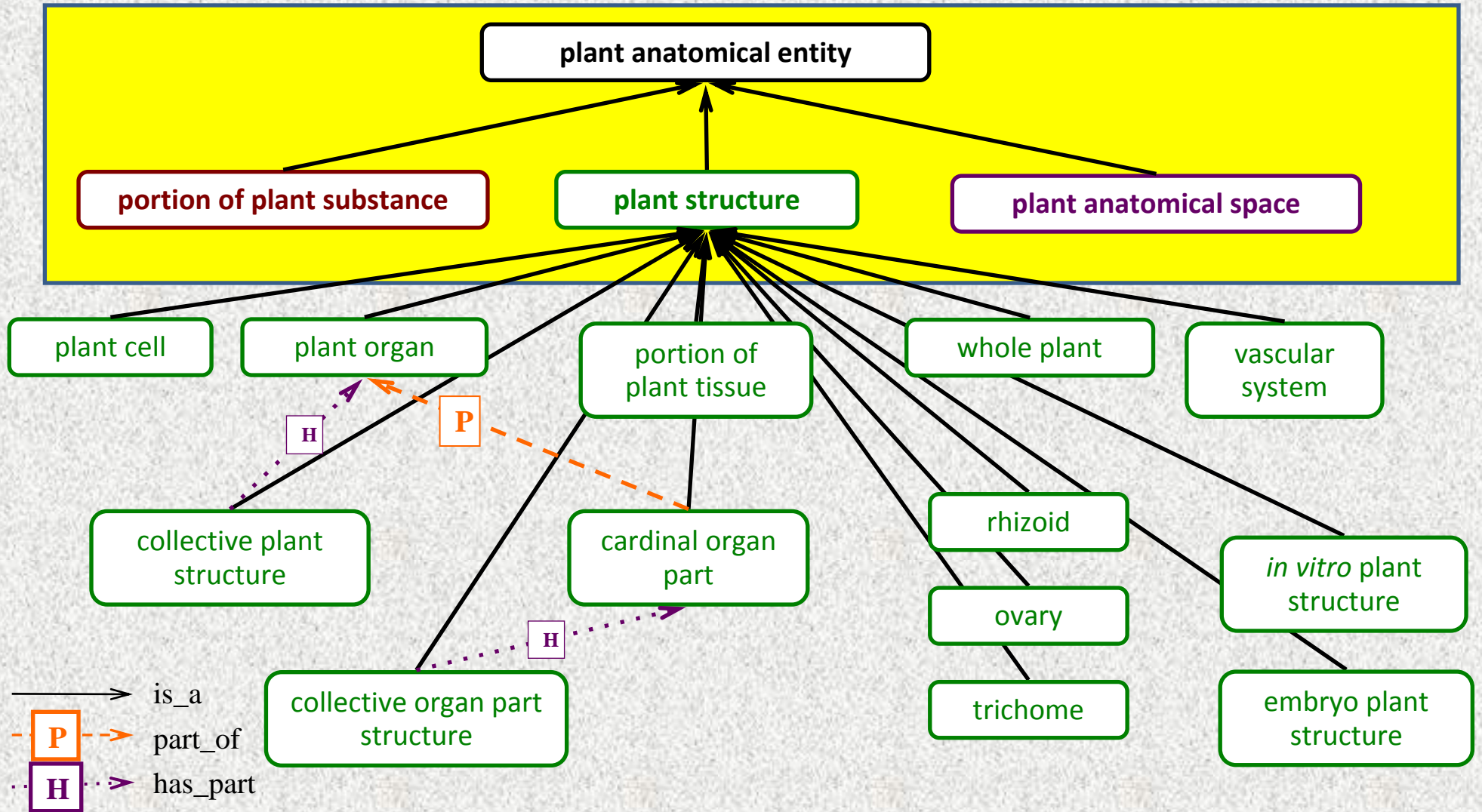
Relations in the PO allow for an accurate expression of biology

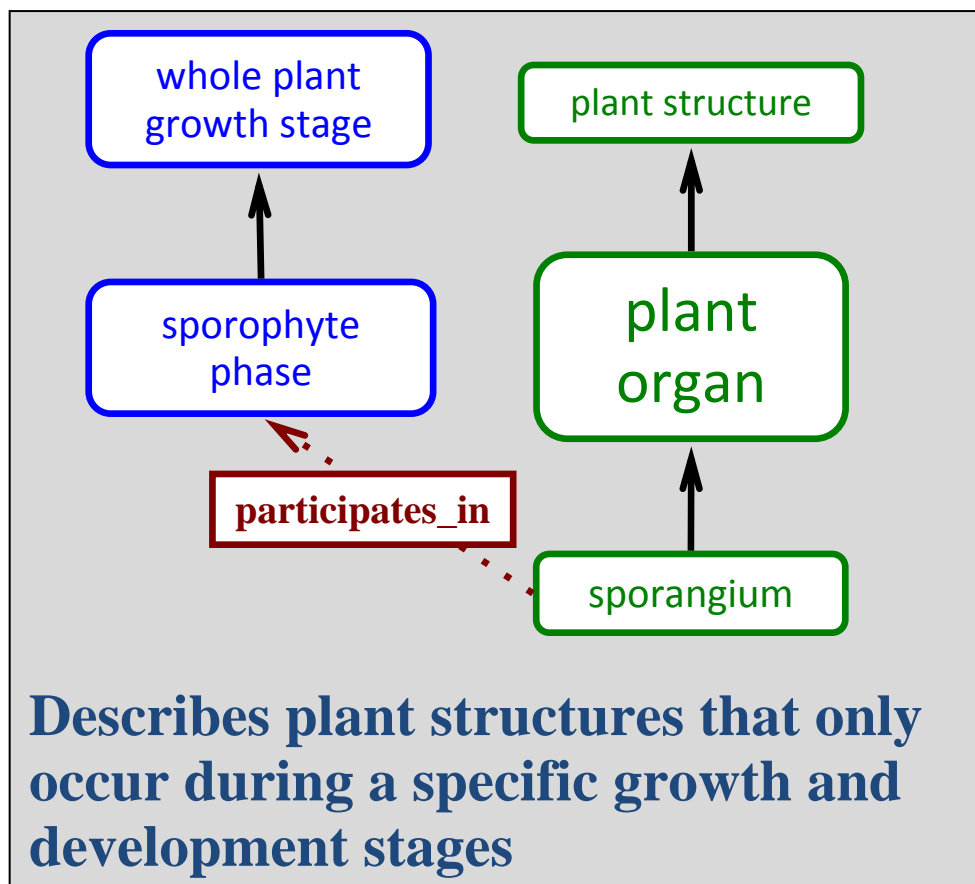*is_a* and *part_of* are the backbone of all anatomical ontologies

has_part allows the PO to handle structural variation among taxa

develops_from describes shared developmental pathways across all taxa

shoot system

is_a

reproductive shoot system

is_a

is_a

inflorescence

has_part

flower

develops_from

infructescence

part_of

part_of

perianth

gynoecium

Reasoner: perianth is *part_of* flower which *is_a* a reproductive shoot system.

So:
 perianth is *part_of* reproductive shoot system

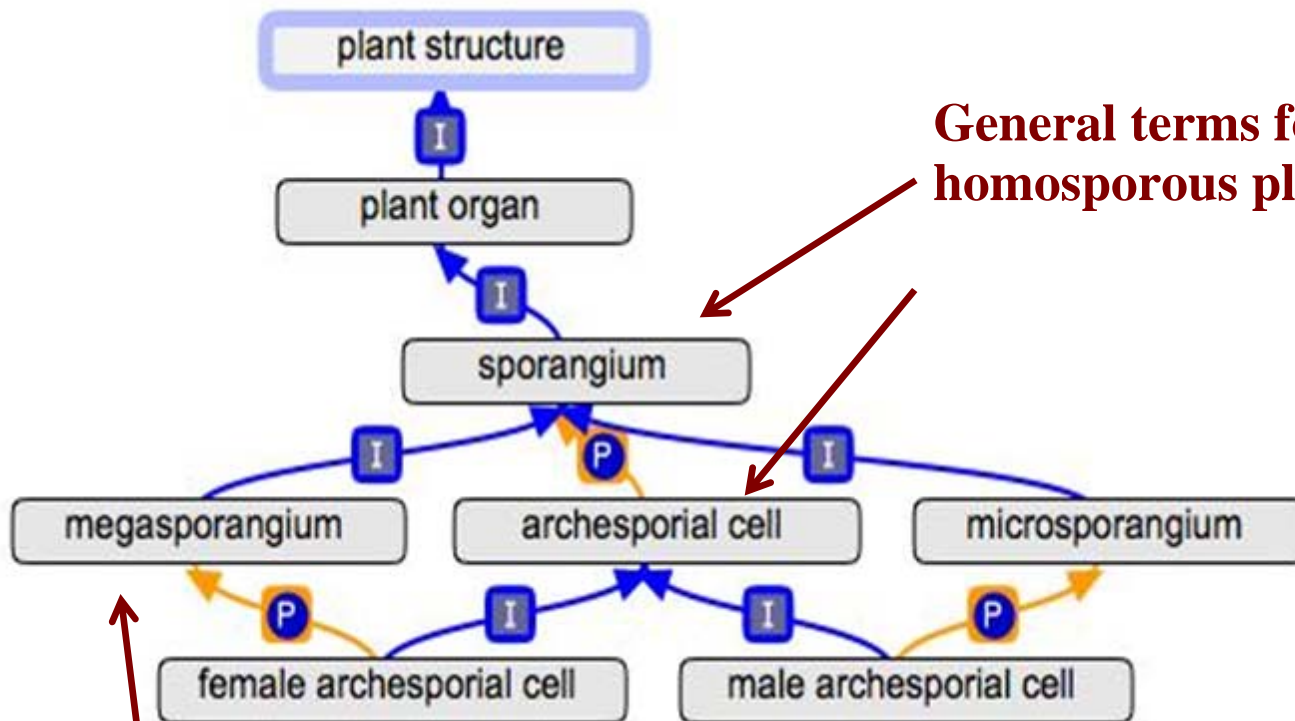# The *participates_in* relation links an anatomical entity to a plant growth or development stage

whole plant growth stage

sporophyte phase

participates_in

plant structure

plant organ

sporangium

Describes plant structures that only occur during a specific growth and development stages

→ is_a

Example:
A **sporangium** *is_a* **plant organ that produces spores** *which participates_in* a **sporophyte phase**

http://analogicalplanet.com/Pages/ContentPages/Mosses/MossIndex.html

General and more-specific ontology terms span plant kingdom
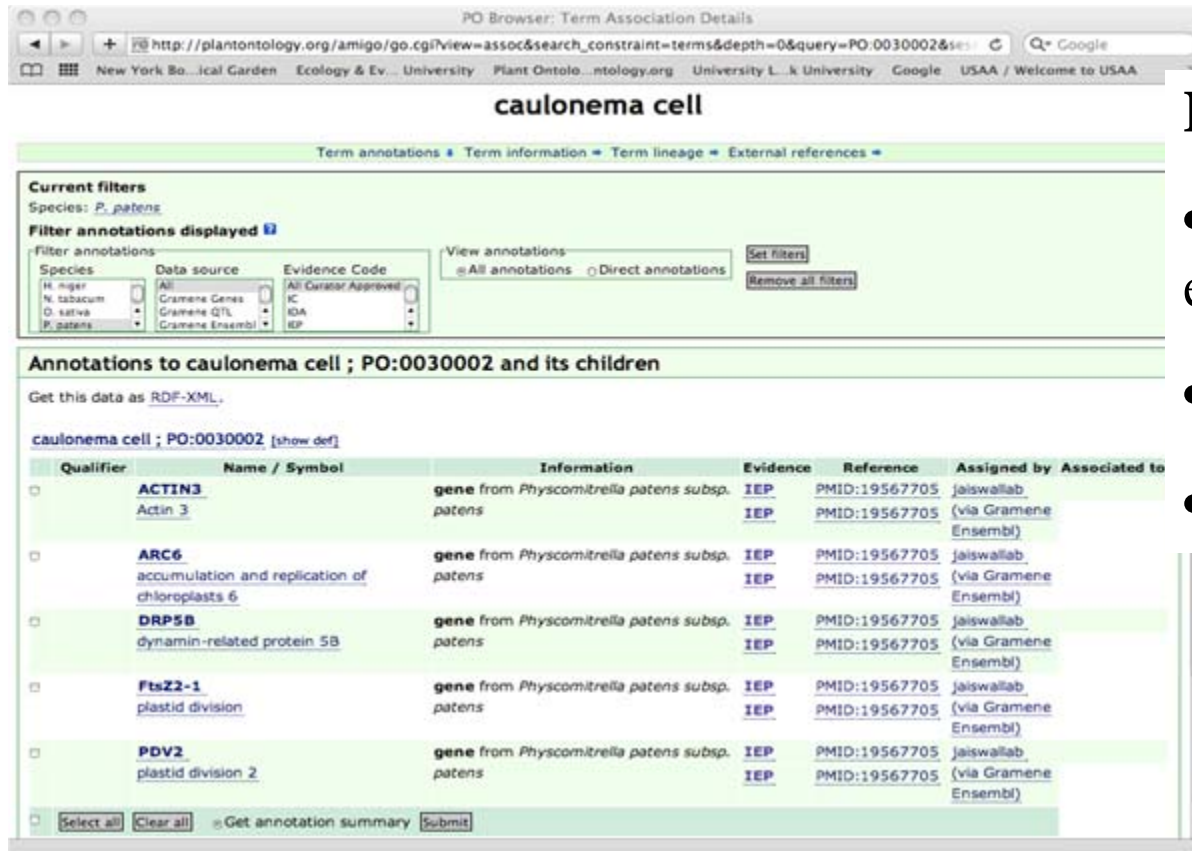
The Plant Ontology is…
…a database resource for plant science

Links to associations from:

• gene expression experiments

• EST and QTL datasets

• mutant phenotype screens

~2.2 million associations for 1320 PO terms covering 17 species

# The Plant Ontology facilitates comparative plant genomics

Annotations to leaf primordium ; PO:0000017 and its children

Get this data as RDF-XML.

leaf primordium ; PO:0000017 [show def]

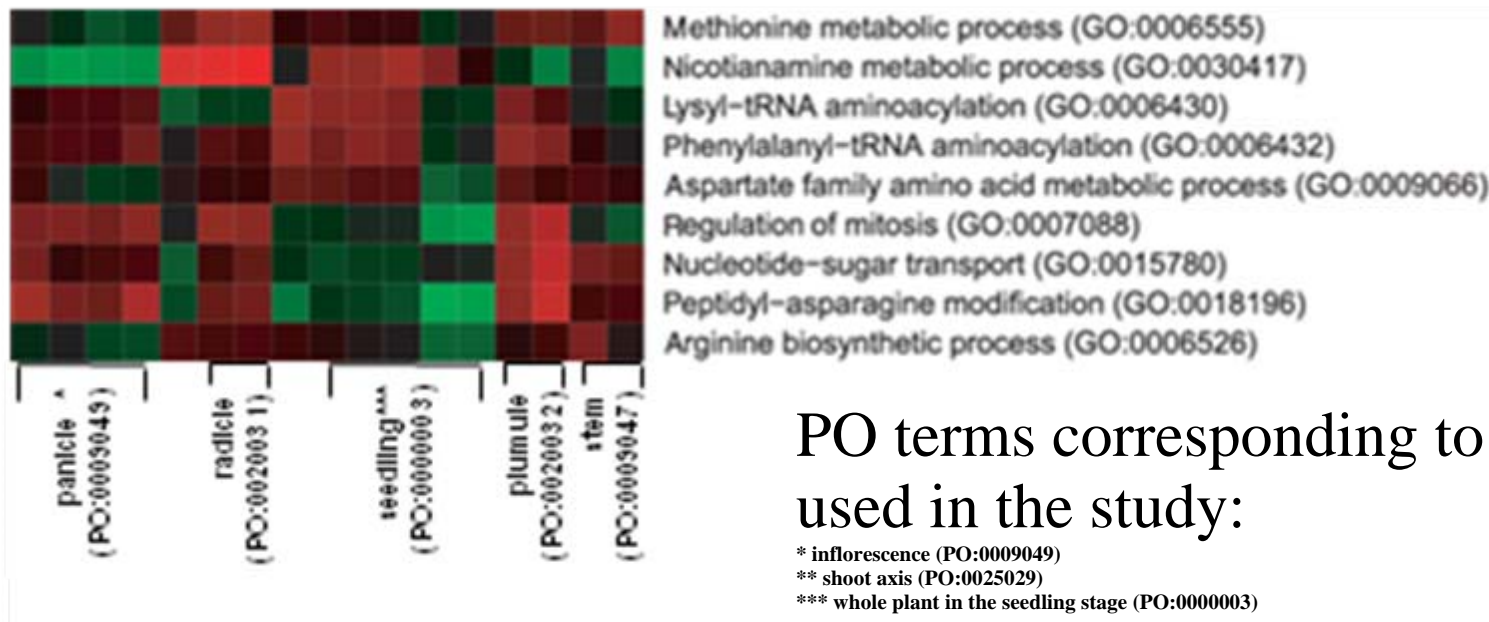|	Qualifier	Name / Symbol	Information	Evidence	Reference	Assigned by	Associated to
☐		**AN3** AT5G28640	**gene** from *Arabidopsis thaliana*	IEP	PMID:15960617	TAIR	GO
☐		**ARF4** AT5G60450	**gene** from *Arabidopsis thaliana*	IDA	PMID:16199616	TAIR	GO
☐		**AS2** AT1G65620	**gene** from *Arabidopsis thaliana*	IDA	PMID:17559509	TAIR	GO
☐		**AT1G13400.1** AT1G13400	**gene** from *Arabidopsis thaliana*	IDA	PMID:16554365	TAIR	GO
☐		**AT1G22840.1** AT1G22840	**gene** from *Arabidopsis thaliana*	IDA	PMID:16113211	TAIR	GO
☐		**ATARP6** AT3G33520	**gene** from *Arabidopsis thaliana*	IDA	PMID:16155178	TAIR	GO
☐		**ATGA2OX2** AT1G30040	**gene** from *Arabidopsis thaliana*	IDA	PMID:16139211	TAIR	GO
☐		**ATGA2OX4** AT1G47990	**gene** from *Arabidopsis thaliana*	IDA	PMID:16139211	TAIR	GO
☐		**ATH1** AT4G32980	**gene** from *Arabidopsis thaliana*	IEP	PMID:17908157	TAIR	GO
☐		**ATHB-12**	**gene** from *Arabidopsis*	IDA	PMID:15604708	TAIR	GO

Cross-taxa comparisons:
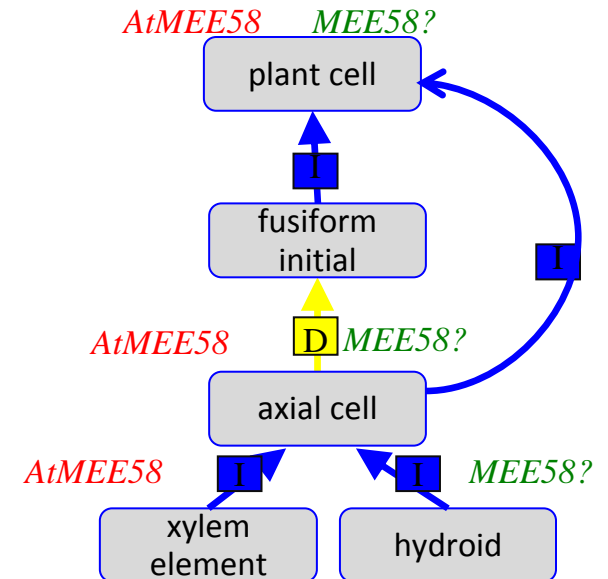
Annotations allow for data analysis:

Annotations may be created based on microarray, EST, QTL, protein, germplasm, phenotype or other data sets, or whole genome sequencing projects.

Example microarray data set with PO and GO annotations:

PO terms corresponding to synonyms used in the study:

* inflorescence (PO:0009049)
** shoot axis (PO:0025029)
*** whole plant in the seedling stage (PO:0000003)

Contact us if you are interested in providing and maintaining annotations files for your project

Collaborative development of the PO: descriptors and annotations

Recent Examples:
- Addition of 1.5 million new associations between *Zea mays* (maize) gene models and Plant Ontology terms (October 2011)

- ~80 new anatomy terms for the *Physcomitrella*- Moss Computational Biology Resource

- Added ~ 82,000 new annotations to Moss genomics data (Jan 2012)

PO Web Services

Plant Ontology terms, synonyms, and definitions are now available via RESTful* web services

Request terms by keyword:

```
{
  - PO_term_search_response: [
    - {
        match: "banner petal",
        match_type: "term",
        accession_id: "PO:0025324"
    },
    - {
        match: "keel petal",
        match_type: "term",
        accession_id: "PO:0025326"
    },
    - {
        match: "petal",
        match_type: "term",
        accession_id: "PO:0009032"
    },
    - {
        match: "petal abaxial epidermis",
        match_type: "term",
        accession_id: "PO:0006052"
    },
    - {
        match: "petal adaxial epidermis",
        match_type: "term",
        accession_id: "PO:0006053"
    },
    - {
        match: "petal apex",
```

...and use the real-time results† in your application
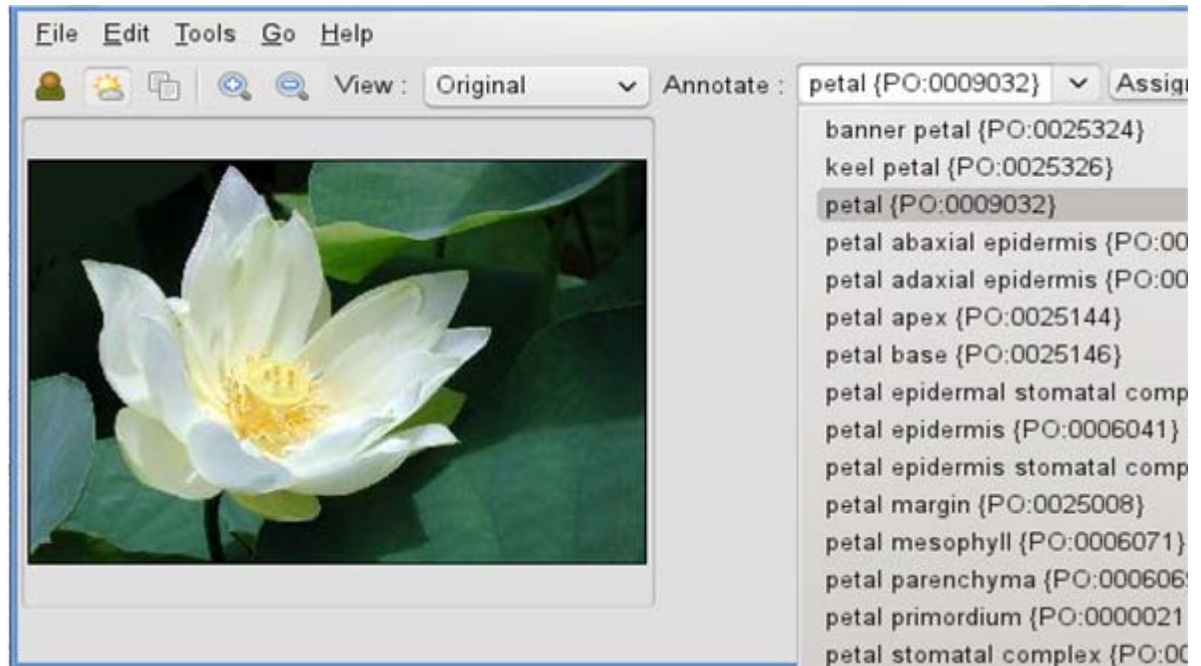
Detailed documentation for application developers is available on the PO web site

* REST: *Representational State Transfer (an architecture for web-based data communication)*
† *Web service results are encoded in JSON, a lightweight data-interchange format*
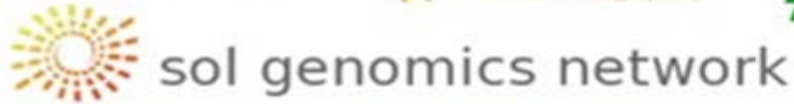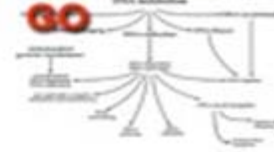
For more information: PO Events at PAG 2012

- **Non-seed plants Workshop:** Saturday, Jan 14th, 5:10 pm, Sunrise room

- **Plant Phenotypes Workshop:** Sunday, Jan 15th, 9:10 am, Golden west

- **Computer Demo**: Monday Jan 16th, 12:50pm

- **Poster # P0939**: Monday Jan 16th: 10:00 am - 11:30 am (even), 3:00 pm - 4:30 pm (odd)

- **Plant Genome Outreach Consortium Outreach booth**
 in exhibit hall:
Sunday, Jan 15th, 3 pm – 8:30 pm
Monday, Jan 16th, 9:30 am – 5 pm
Tuesday, Jan 17th, 9:30 am – 3 pm

Participants and Collaborators:

Cell Ontology