PHENO 2022

TEMPO Réseau National d'Observatoires de la Phénologie

Phenology of plant pathogenic fungi: why and how ?

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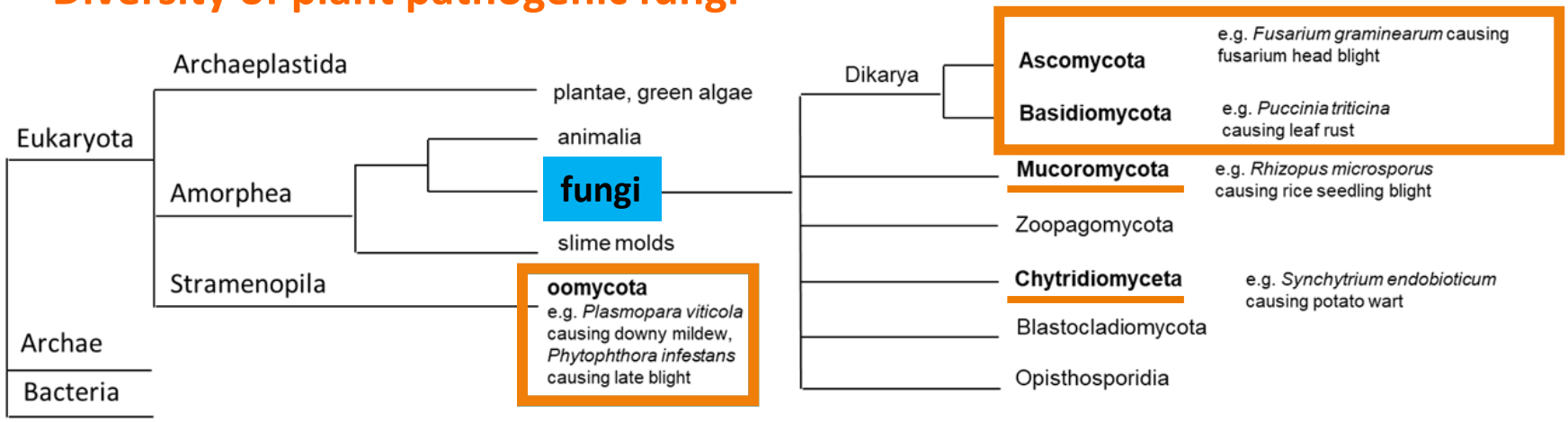
Pathogenic fungi: what (who) are they?

➢ Diversity of plant pathogenic fungi



Fungal &
fungal-like (oomycota)

≈

2 to 4.10^6 species.

Pathogenic

≈

8 to 10k species.

=> Major losses in global food production.

Burki et al., 2019; James et al., 2020;
Li et al., 2021; Fisher et al., 2012

Phenology of plant pathogenic fungi

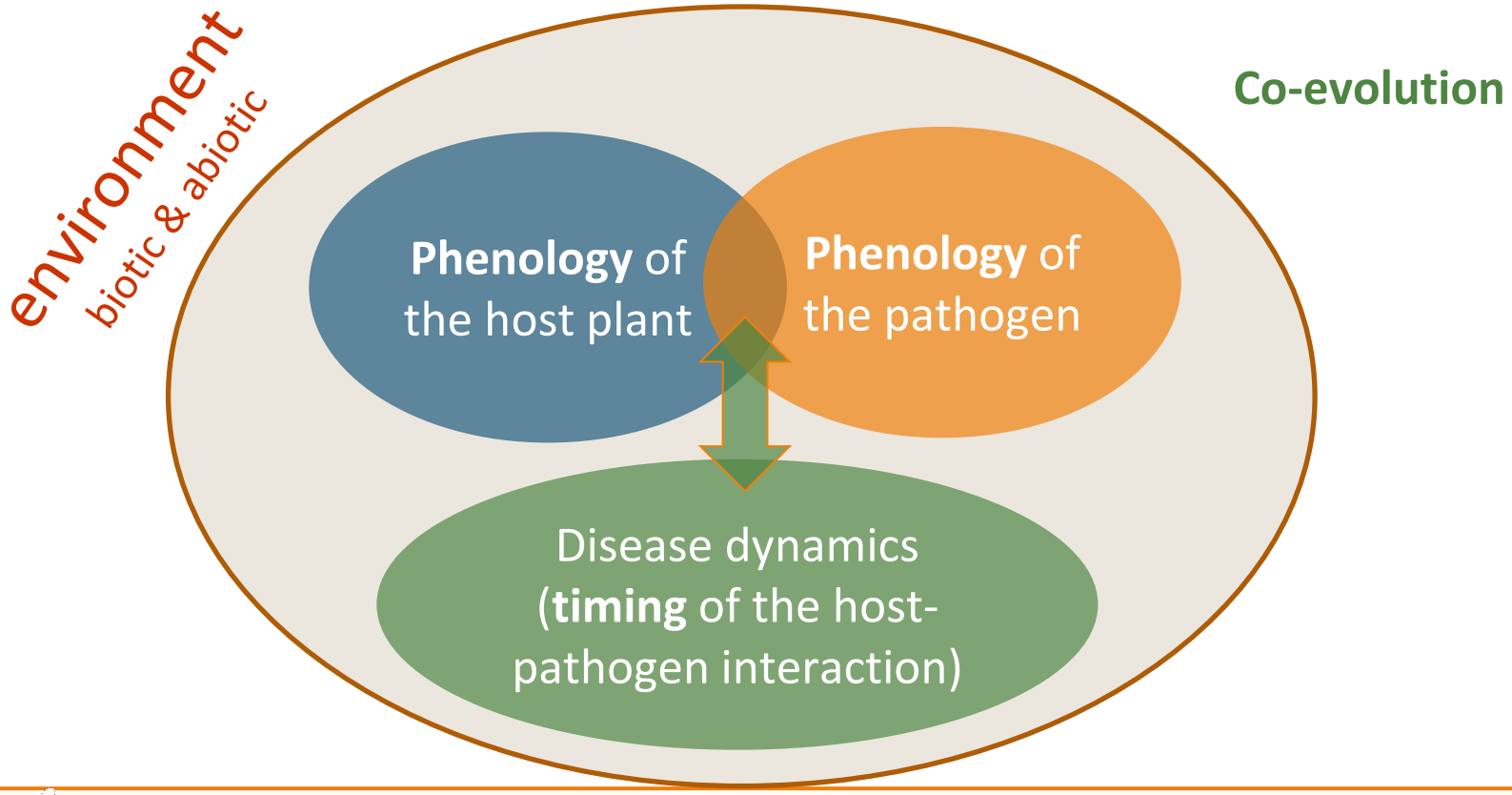
fitness, dispersal patterns, species interactions and ecosystem functioning…

Phenology → **Ecology and evolution**

Phenology of plant pathogenic fungi

fitness, dispersal patterns, species interactions and ecosystem functioning…

Phenology → **Ecology and evolution**



Forest & Miller-Rushing 2010; Dickie et al 2020; Grulke 2011

Phenology of plant pathogenic fungi

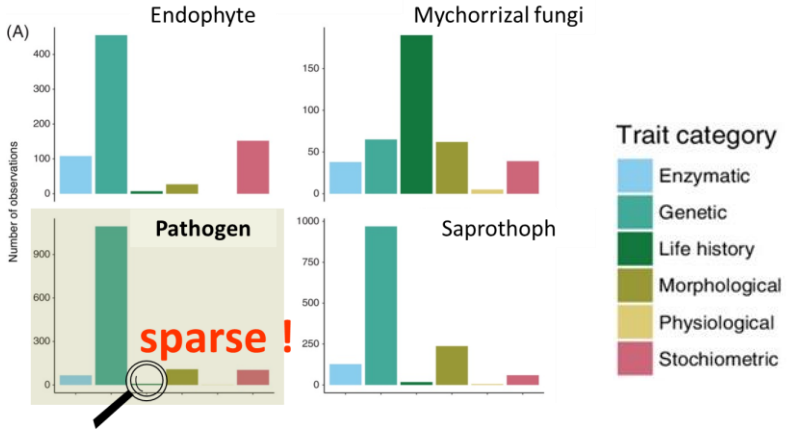
➢ **Is the phenology of fungi phenology studied?**

1. No !

In the literature "*phenology*" for plant pathogenic fungi

-> 1 ref "pathogen phenology" (Desprez-Loustau et al., 2010
-> 2 refs "disease phenology" (Clay et al., 2020; Daugherty et al., 2017)

2. But life history traits
may be considered as "phenology"



Fungal fruiting, spore release,
Latency period, cycle length…
➡ Sparse in the databases

Fungal Functional Trait Database (FunFun), Zanne et al., 2020

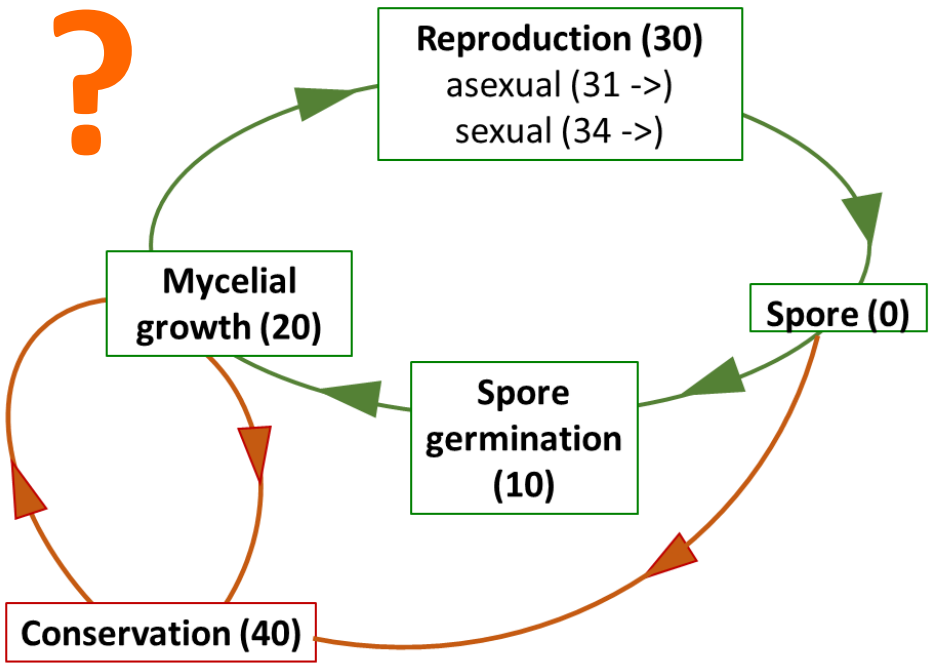
FunScale: a common & global phenological scale

- **Would the BBCH scale be a guideline for building such a scale for pathogenic fungi ?**

Principle Phase	BBCH	Name
Vegetative	00–09	Germination
	10–19	Leaf development
	20–29	Tillering
	30–39	Stem elongation
	40–49	Booting
Reproductive	50–59	Heading
	60–69	Flowering
Maturity	70–79	Development of fruit
	80–89	Ripening
	90–99	Senescence
Transplanting	00–19	Transplanting, recovery (rice only)

Zadoks et al., 1974

Simplified biological cycle of pathogenic fungi

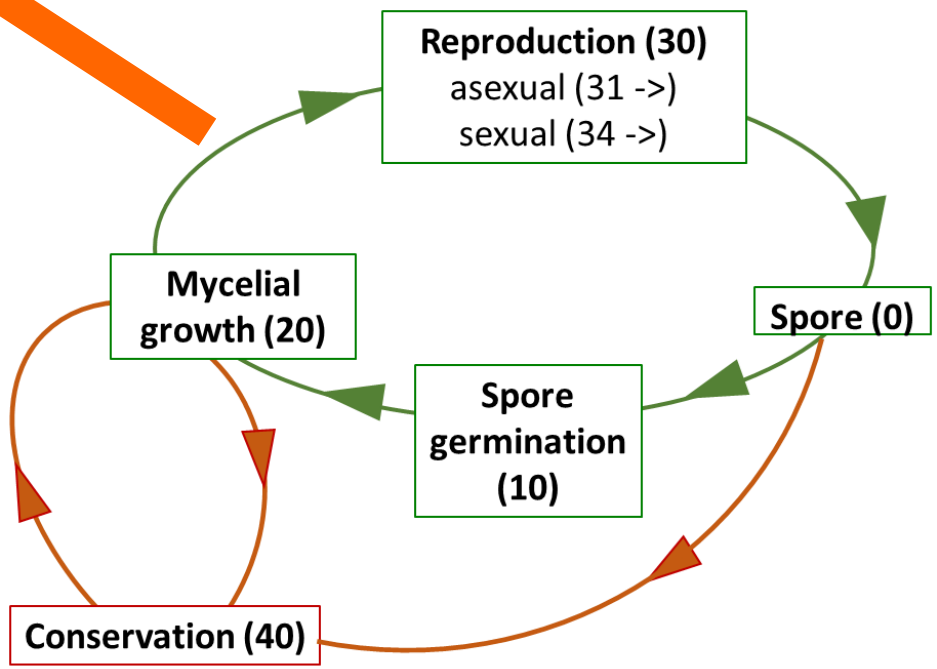


FunScale: a common & global phenological scale

- **Would the BBCH scale be a guideline for building such a scale for pathogenic fungi ?**

Main stage code	Name of the main stage
0	Spore
10	Spore germination
20	Mycelial growth
30	Reproduction
40	Conservation

Simplified biological cycle of pathogenic fungi



FunScale: a common & global phenological scale

- **Would the BBCH scale be a guideline for building such a scale for pathogenic fungi ?**

Main stage code	Name of the main stage
2	
30	
40	

Main stage code	Name of the main stage	Secondary stage code	Name of the secondary stage
0	Spore	01	Entire spore without mycelium
10	Spore germination	11	Spore germination
		12	Development of the appressorium if existing
20	Mycelial growth	21	Beginning of mycelium growth (without ramification)
		22	Appearance of ramifications
		23	Mycelium in active growth
30	Reproduction	31	Asexual reproduction (AR) - Appearance of sporocarps/ conidiophores (immature)
		32	AR- Mature sporocarps/ conidiophores
		33	AR - Sporulation
		34	Sexual Reproduction (SR) - Formation of gametangium and meeting of gametes
		35	SR - Immature fructification
		36	SR - Mature fructification
		37	SR - Sporulation
40	Conservation	41	Conservation of mycelium or spores
		42	After unfavorable conditions: mycelium decondensation
		43	Decondensed mycelium

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FunScale: a common & global phenological scale

- **Would the BBCH scale be a guideline for building such a scale for pathogenic fungi ?**

Main stage code	Name of the main stage	Secondary stage code	Name of the secondary stage	Tertiary stage code	Name of the tertiary stage	Taxonomic group
0	Spore	01	Entire spore without mycelium	01.1	Spore from sexual reproduction (basidiospore)	Basidiomycota
				01.2	Spore from asexual reproduction (spermatium)	Basidiomycota
				01.3	Spore from asexual reproduction (aeciospore)	Basidiomycota
				01.4	Spore from asexual reproduction (uredospore)	Basidiomycota
				01.5	Spore from asexual reproduction (teliospore)	Basidiomycota
				01.6	Spore from sexual reproduction (ascospore)	Ascomycota
				01.7	Spore from asexual reproduction (conidium)	Ascomycota
				01.8	Spore from sexual reproduction (sporangium)	Oomycota
				01.9	Spore from asexual reproduction (sporangium)	Oomycota
				01.10	Spore from sexual reproduction (zoospore)	Oomycota/ Chytridiomycota
				01.11	Spore from asexual reproduction (zoospore)	
10	Spore germination	11	Spore germination			all phyla
		12	Development of the appressorium if existing			
20	Mycelial growth	21	Beginning of mycelium growth (without ramification)			all phyla
		22	Appearance of ramifications			all phyla
		23	Mycelium in active growth	23.1	Branched mycelium in active growth (heterothallic)	Heterothallic fungus
				23.2	Branched mycelium in active growth (homothallic)	Homothallic fungus
30	Reproduction	31	Asexual reproduction (AR) - Appearance of sporocarps/ conidiophores (immature)			all phyla
		32	AR- Mature sporocarps/ conidiophores	32.1	spermogonia	Basidiomycota
				32.2	aecium	Basidiomycota
				32.3	uredium	Basidiomycota
				32.4	telium (teleutosorus)	Basidiomycota
				32.5	naked conidiophores	Ascomycota
				32.6	acervulus	Ascomycota
				32.7	pycnidium	Ascomycota
				32.8	sporodochium	Ascomycota
				32.9	synnema	Ascomycota
				32.10	sporangiophore	Oomycota
				32.11	sporangium (bag not a spore)	Oomycota/Chytridiomycota
		33	AR - Sporulation	33.1	less than 10% of sporocarps	
				33.5	50% of sporocarps	
				33.9	90% of sporocarps	
		34	Sexual Reproduction (SR) - Formation of gametangium and meeting of gametes	34.1	spermatium	Ascomycota, Basidiomycota
				34.2	oogone, antheridium	Oomycota
		35	SR - Immature fructification			
				36.1	basidium	Basidiomycota

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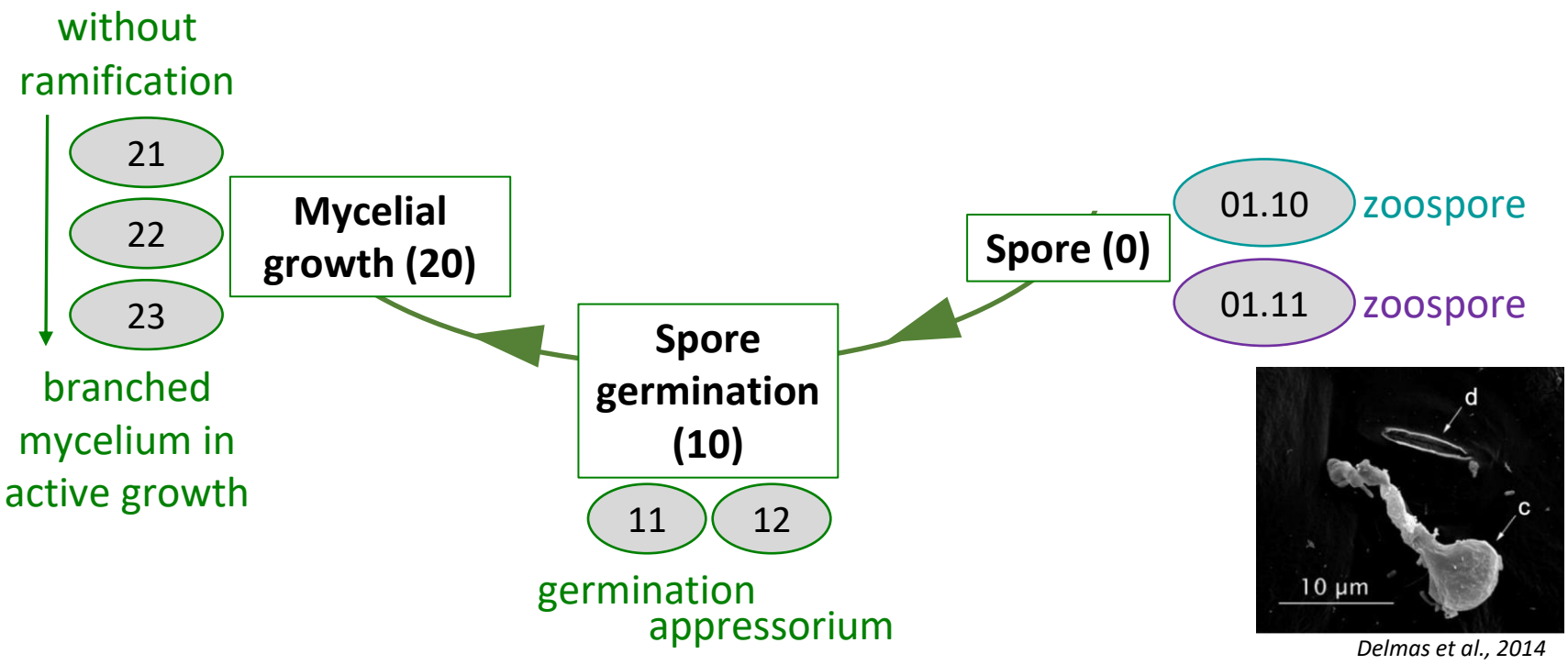
FunScale: let's play!

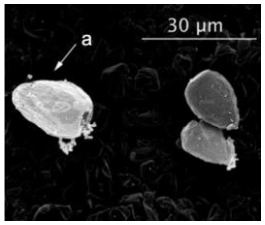
- **Oomycota (ex: *Plasmopara viticola*)**



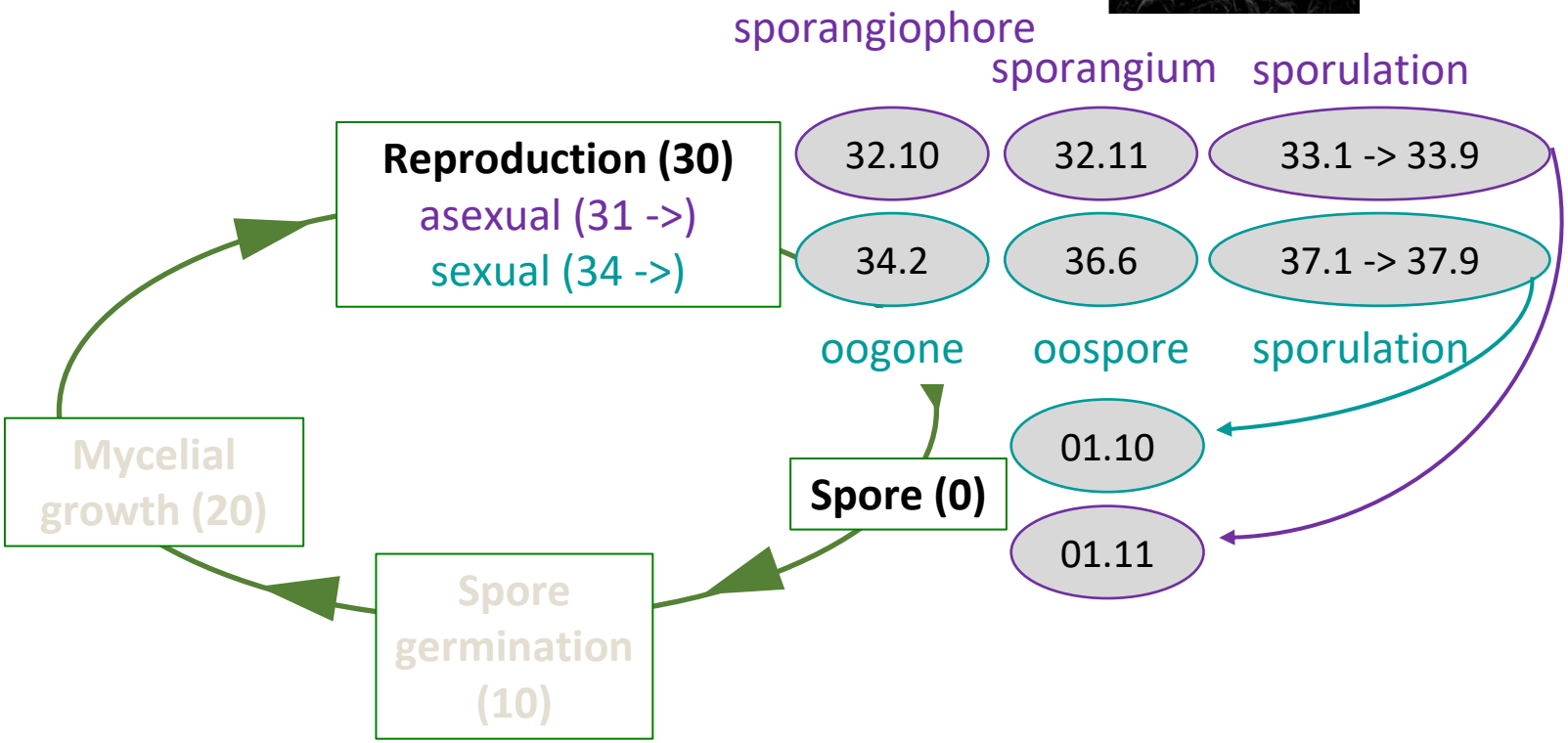
Delmas et al., 2014

FunScale: let's play!

Delmas et al., 2014

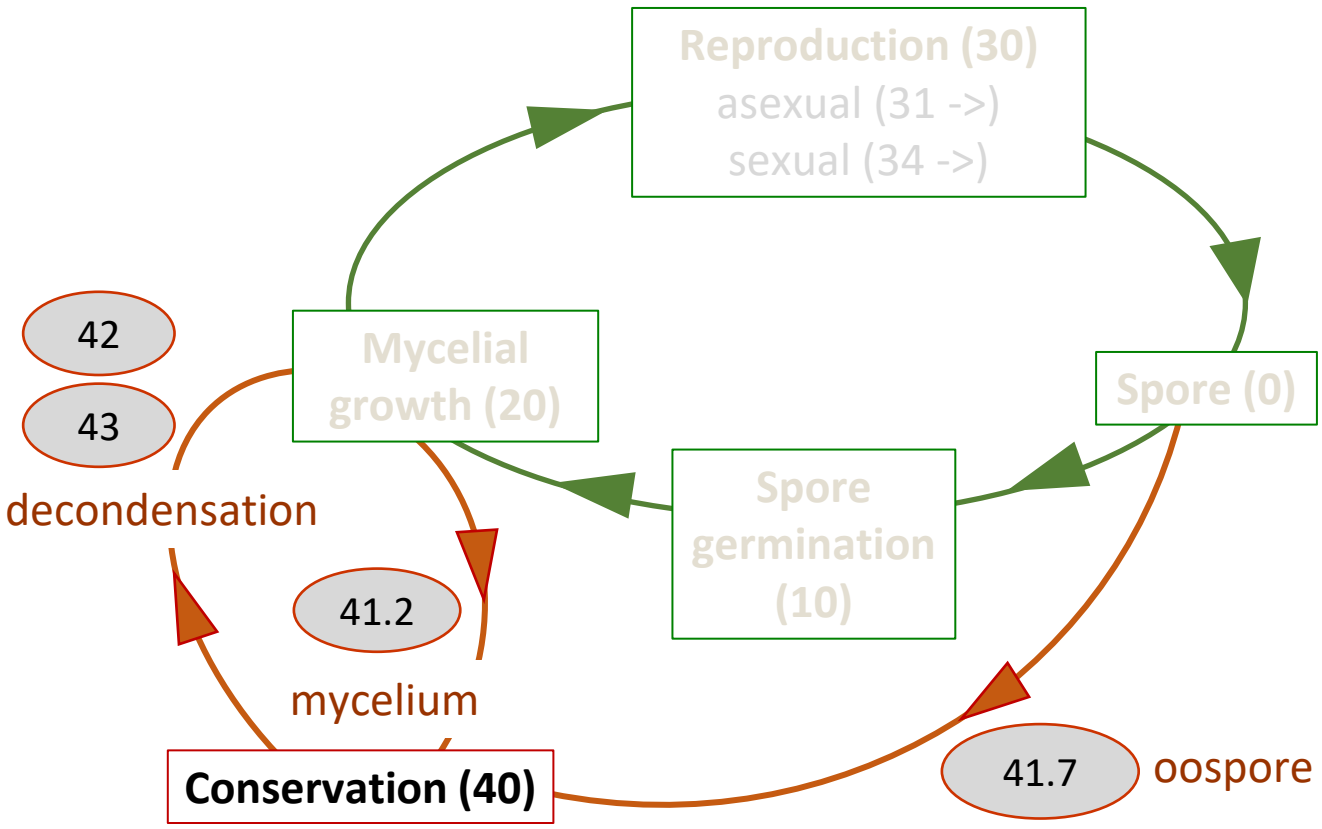


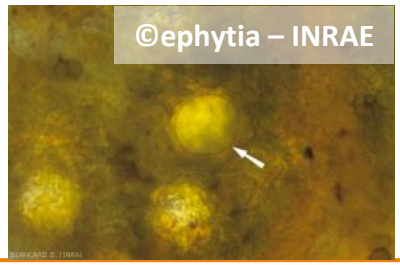
➢ **Oomycota (ex: *Plasmopara viticola*)**



FunScale: let's play!

- **Oomycota (ex: *Plasmopara viticola*)**





FunScale: a common & global phenological scale

- **We succeeded in doing this one:**

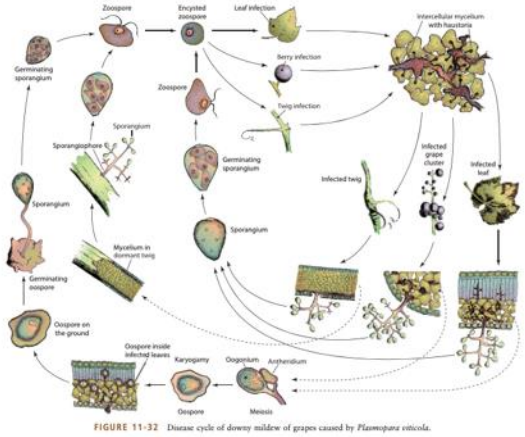


FIGURE 11-32 Disease cycle of downy mildew of grapes caused by *Plasmopara viticola*.

Agrios, 2004

… but what about the other ones ?

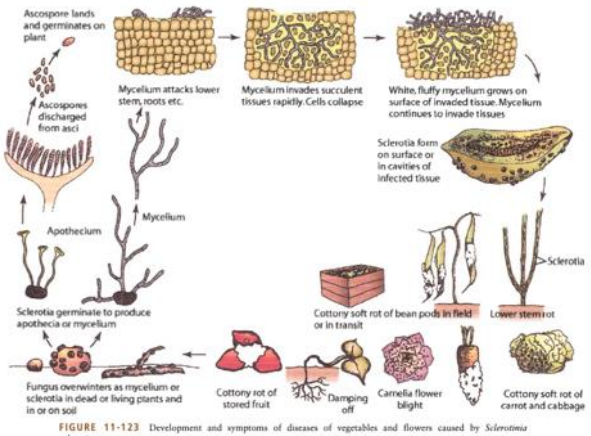


FIGURE 11-123 Development and symptoms of diseases of vegetables and flowers caused by *Sclerotinia sclerotiorum*.

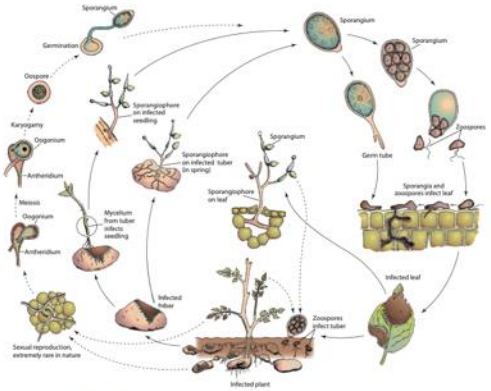


FIGURE 11-29 Disease cycle of late blight of potato and tomato caused by *Phytophthora infestans*.

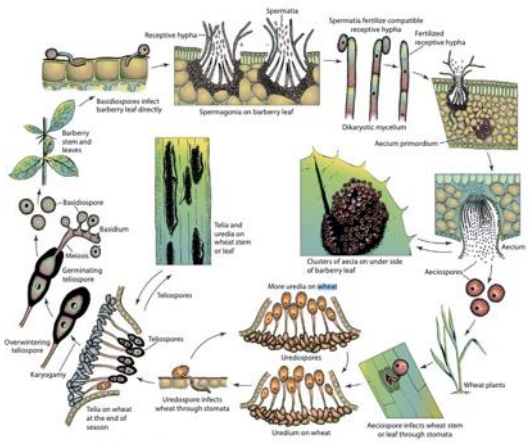


FIGURE 11-134 Disease cycle of stem rust of wheat caused by *Puccinia graminis tritici*.

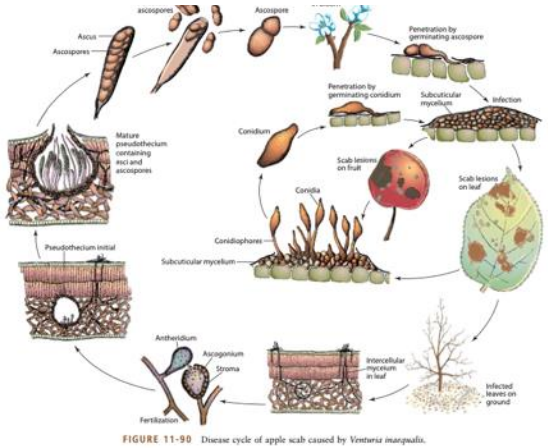


FIGURE 11-90 Disease cycle of apple scab caused by *Venturia inaequalis*.

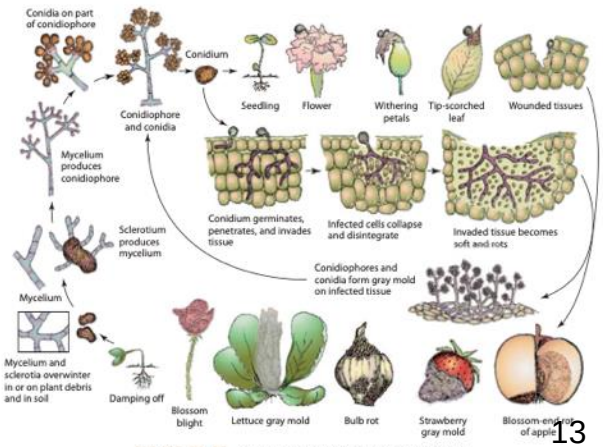
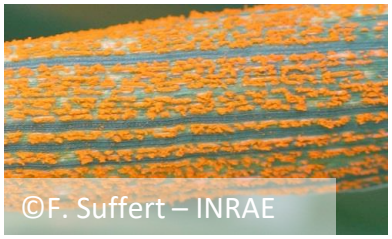


FIGURE 11-97 Disease cycle of *Botrytis* gray mold diseases.

FunScale: a common & global phenological scale

➢ **Basidiomycota (ex: *Puccinia striiformis sp. tritici*)**



spermogonia aecium uredium telium

32.1 32.2 32.3 32.4

Reproduction (30)
asexual (31 ->33.9)
sexual (34 ->37.9)

34.1 35 36.1 basidium

spermatium immature fruct.

01.2 01.3
spermatium aeciospore

Spore (0)

01.4 01.5
uredospore teliospore

01.1 basidiospore

Mycelial growth (20)

Spore germination (10)

Conservation (40)

41.3 teliospore

FunScale: a common & global phenological scale

- **Ascomycota (ex: *Botrytis cinerea*)**

FunScale :

Main stages -> common key development stages

Secondary and tertiary stages -> various pathways (e.g. sexual or asexual reproduction) and organ structures (e.g. spores, fruiting organs) depending on the species

FunScale: what for ?

A global phenological scale to describe a huge diversity of pathogenic fungi. FunScale is a potential tool for:

- **Structuring and combining different databases (and thus share!)**
  => plant health epidemiological monitoring platforms
  => common framework for observation acquisition

- **Identifying phenological changes related to climate, crop management, and land use**

- **Surveying, anticipating, and managing situations at risk of epidemics**
  => tool for modelling (conceptual framework, calibration and evaluation)
  => implement pathogen management strategies (e.g. agroecology based on natural regulations)

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Thank you for your attention

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