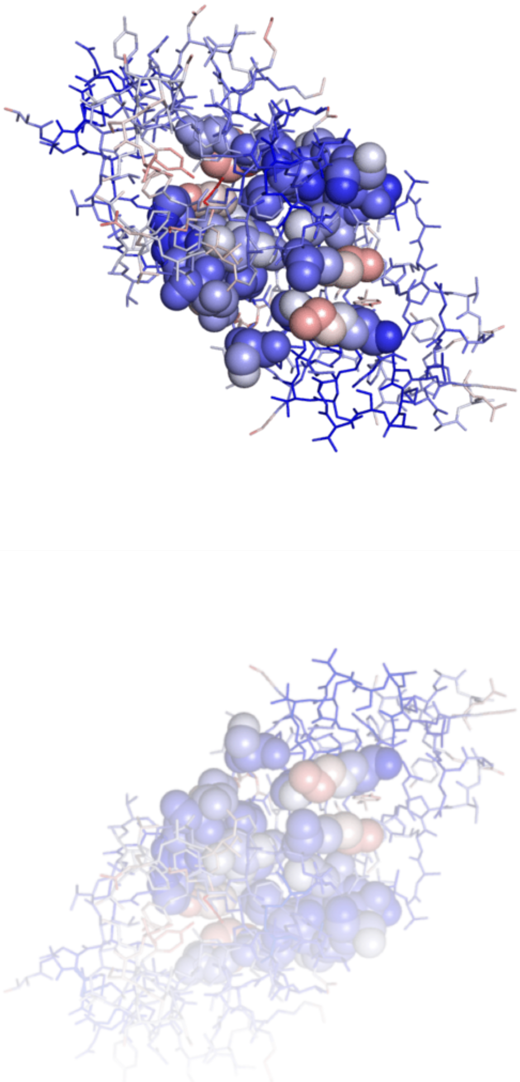
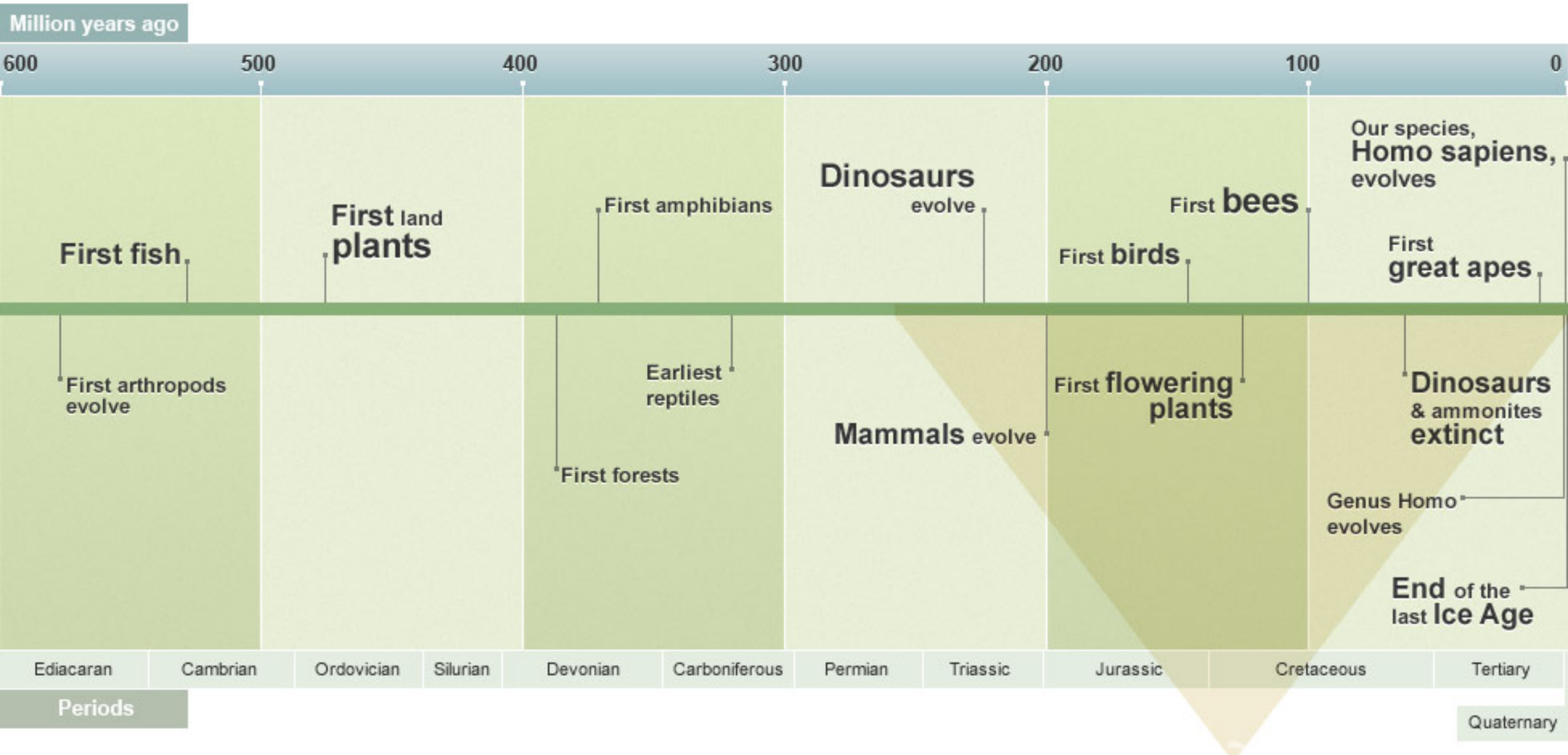


Interação planta-patógeno: comunicação bioquímica e estratégias de defesa e ataque

Dr. Ronaldo J. D. Dalio

ronaldobio@hotmail.com

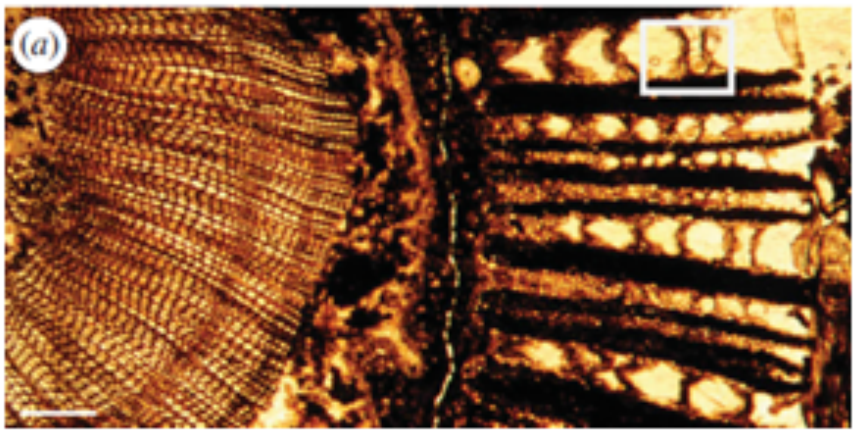


Million years ago
600
500
400
300
200
100
0
First fish
First land plants
First amphibians
Dinosaurs evolve
First birds
First bees
Our species, Homo sapiens, evolves
First great apes
First arthropods evolve
First forests
Earliest reptiles
Mammals evolve
First flowering plants
Dinosaurs & ammonites extinct
Genus Homo evolves
End of the last Ice Age
Ediacaran
Cambrian
Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
Tertiary
Quaternary
Periods

Evidence of parasitic Oomycetes (Peronosporomycetes) infecting the stem cortex of the Carboniferous seed fern *Lyginopteris oldhamia*

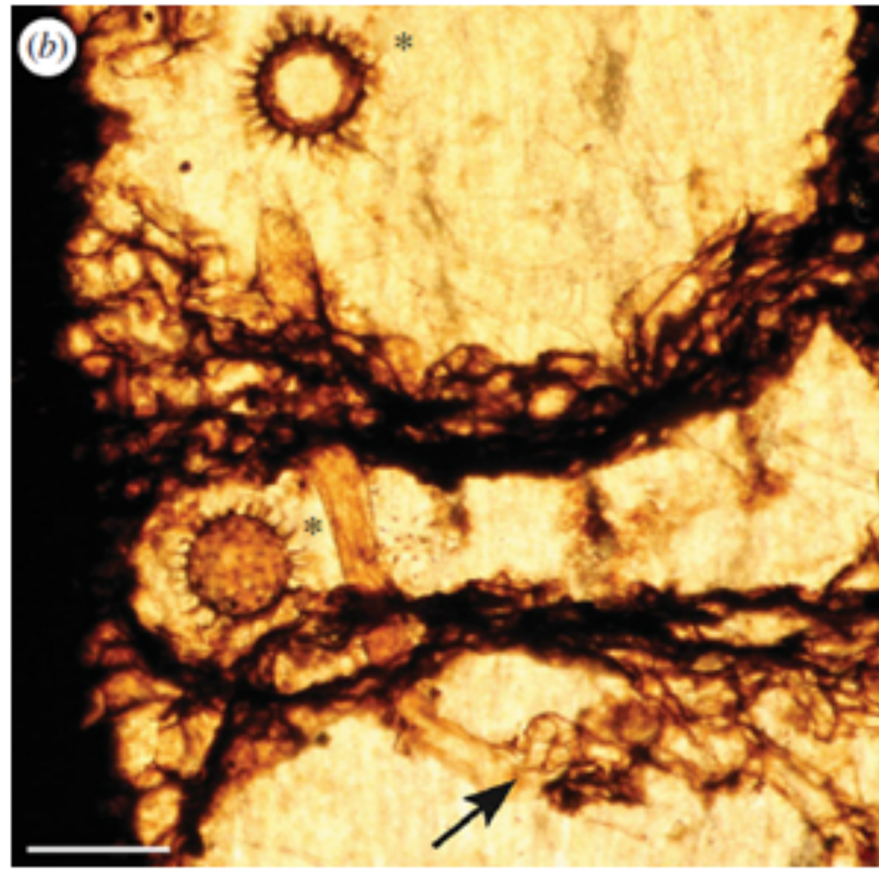
Strullu-Derrien et al. (2010) Proc. R. Soc. B (2011) 278, 675–680

About 320 MY

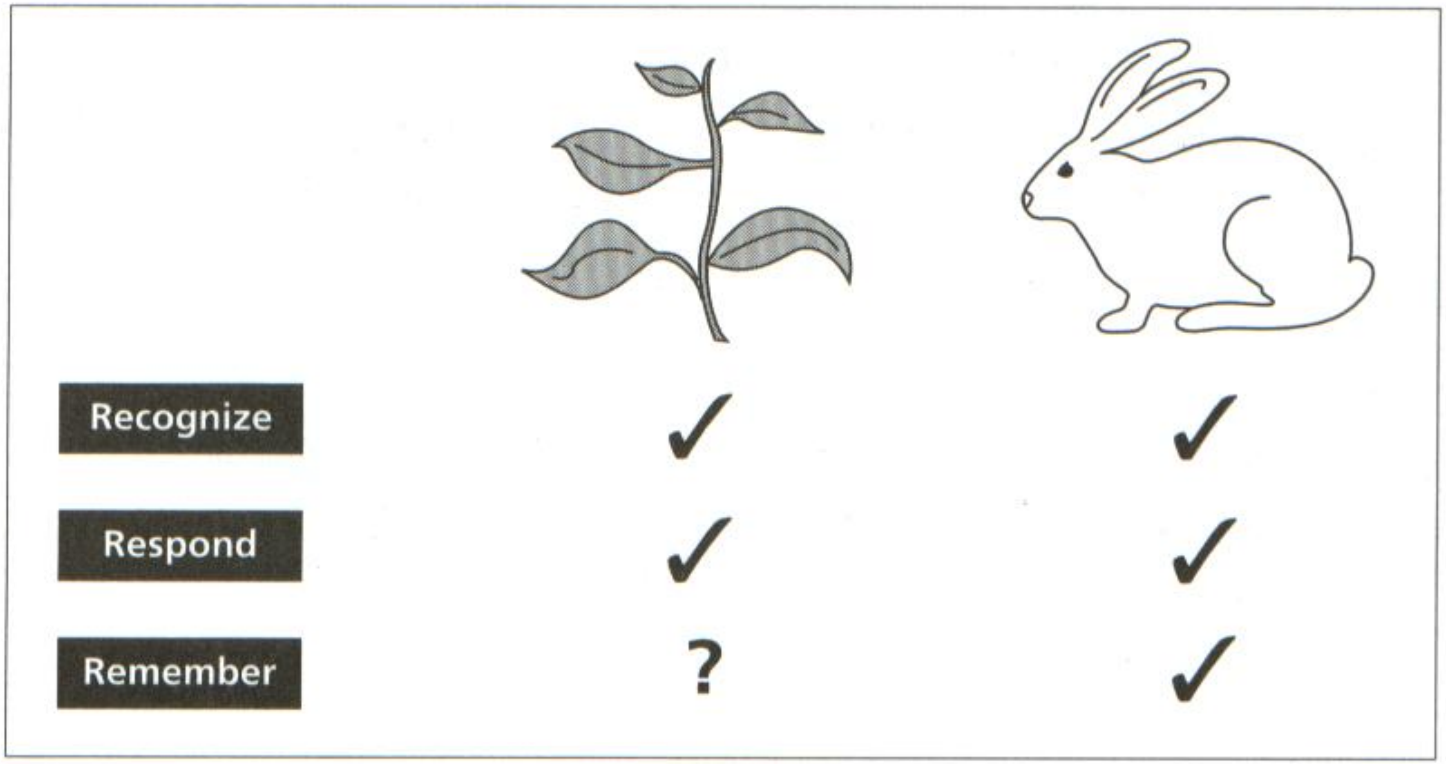


a) Overview of a transverse section of *Lyginopteris oldhamia* stem showing colonization by the Oomycetes in the cortical tissues (frame); the zone in the frame corresponds to

b) Hypha (arrow) and oogonia (asterisk) of *Combresomyces williamsonii* within the parenchyma that separates the fibres of the dictyoxylon outer cortex of the stem.
Note the occurrence of a knot of hyphae (arrow), scale bar, 400 mm.



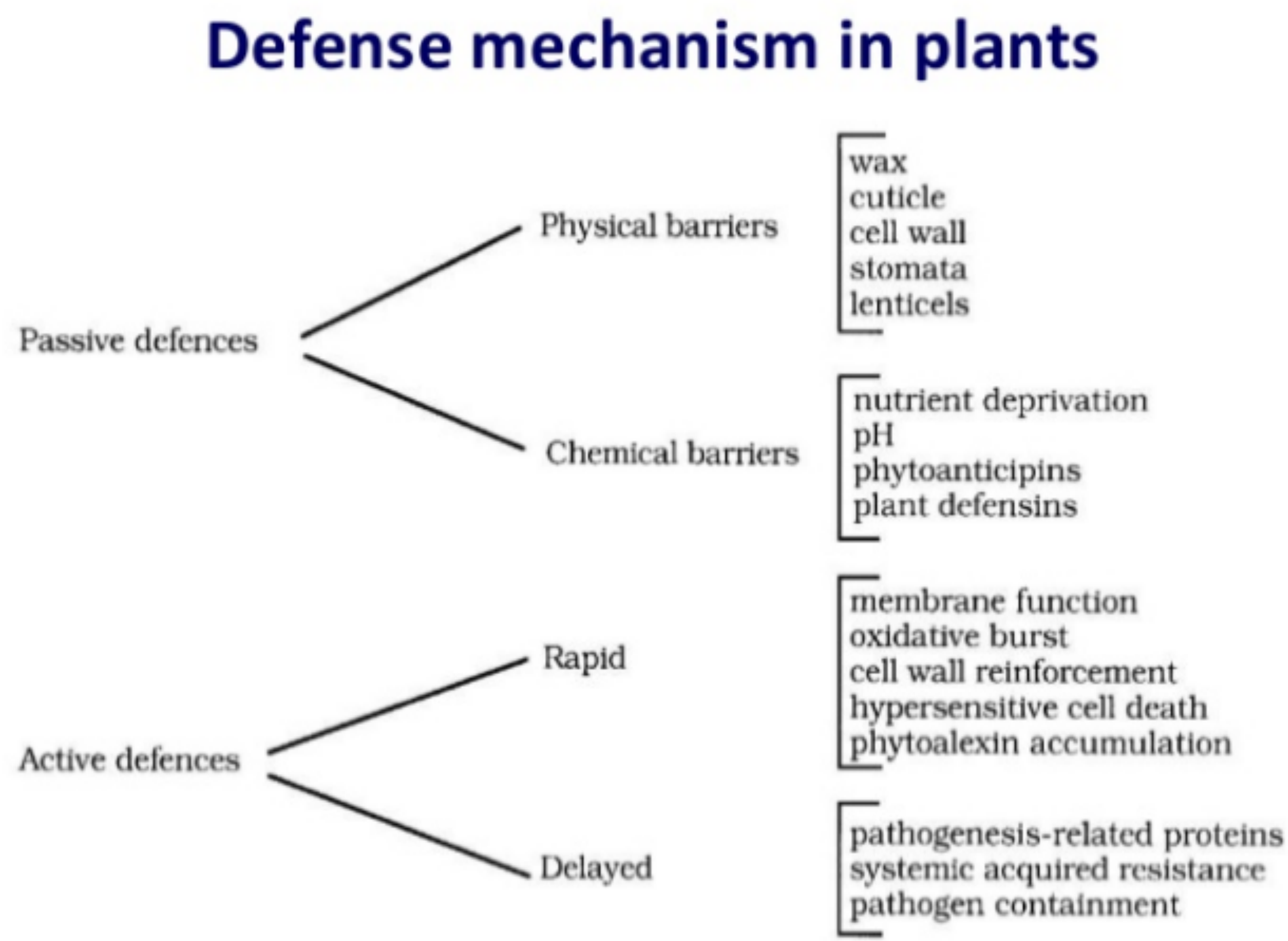
Sistema imune de plantas e animais



Quem são os patógenos de plantas?

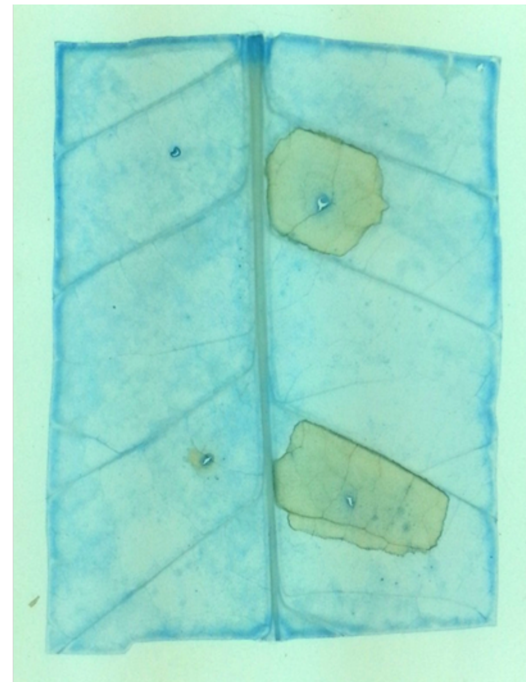
- Virus
- Bactéria
- Fungos
- Oomicetos
- Nematóides

Como as plantas se defendem?



5. Hypersensitive response

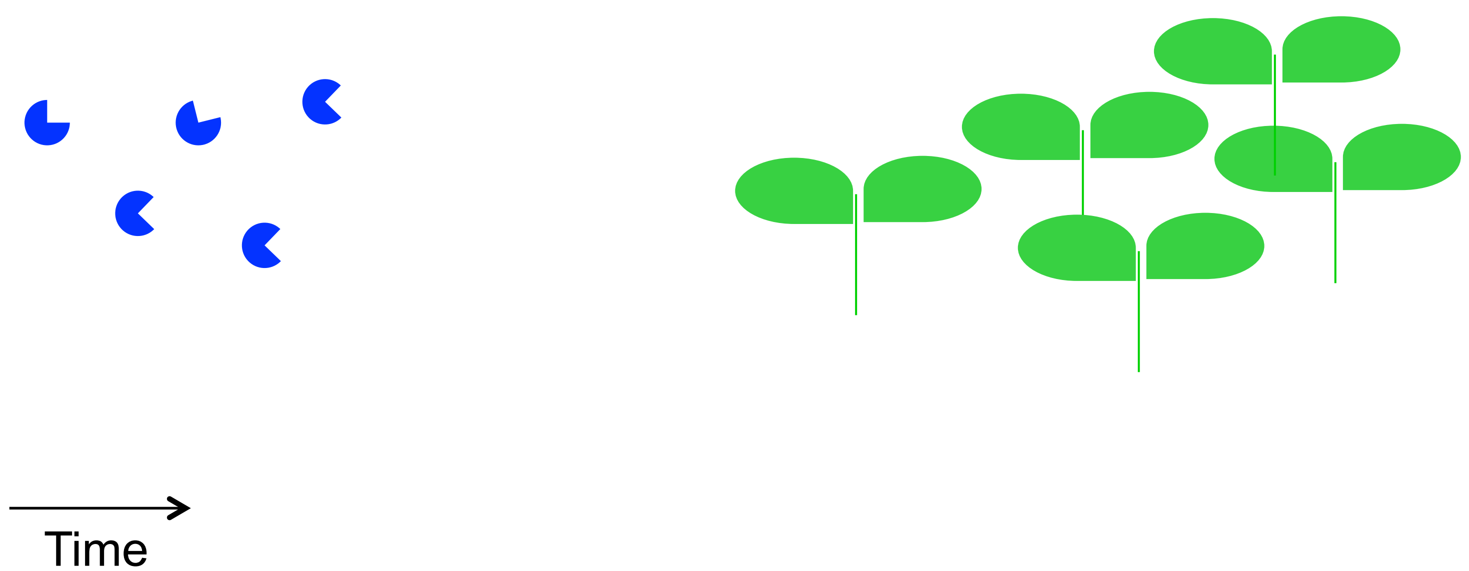
- Rapid death of cells in the local region surrounding an infection.
- Restrict the growth and spread of pathogens to other parts of the plant.
- Favor growth of pathogens with a necrotrophic lifestyle

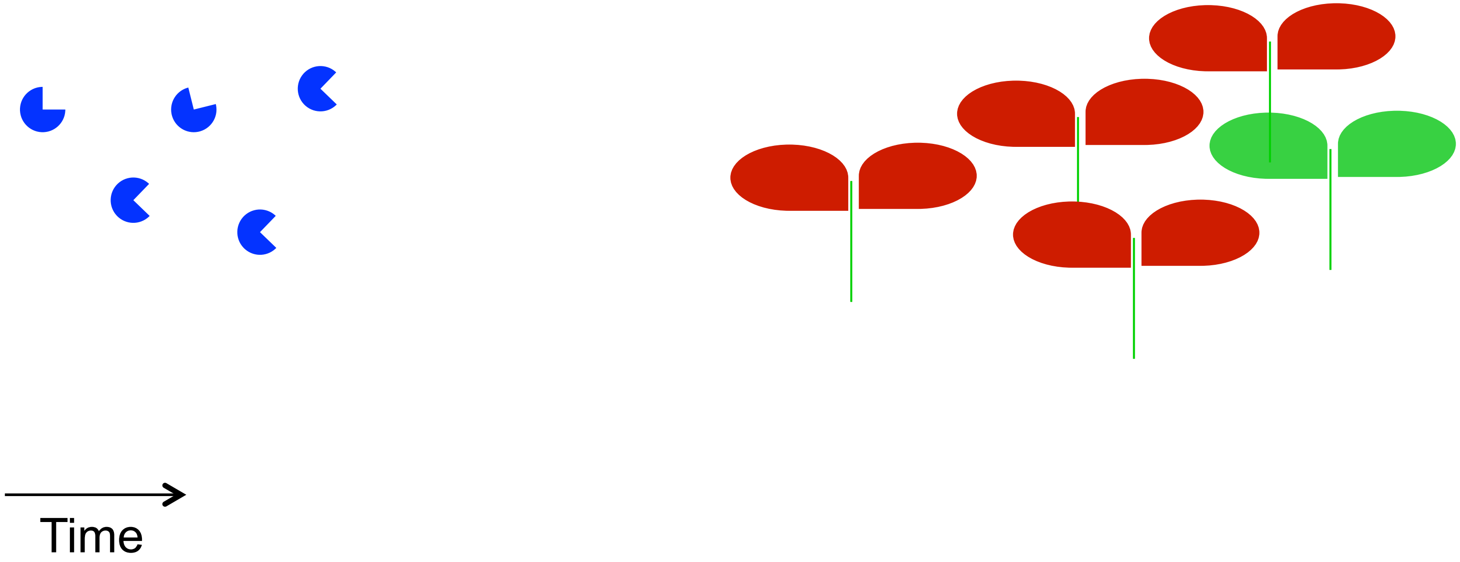
Plant-pathogen interactions

Resistance | Recognition | Susceptibility

Co-evolution
(Arms- race)



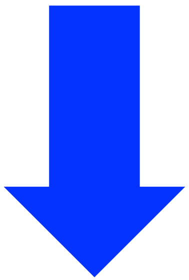
Co-evolution
(Arms- race)



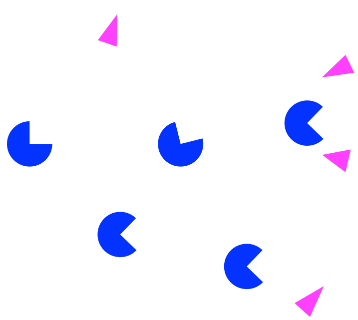
Co-evolution
(Arms- race)

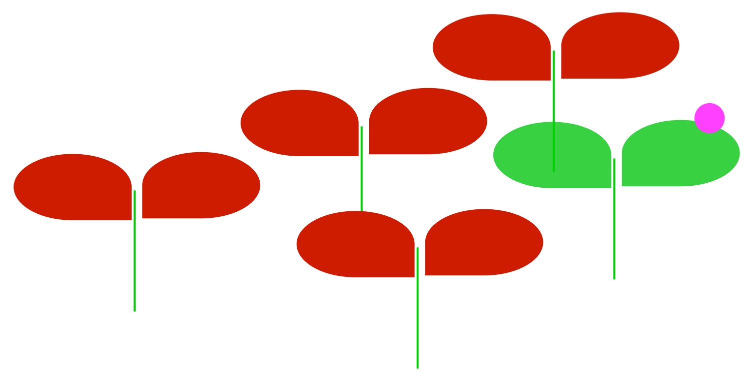
PAMPs= Pathogen Associated molecular patterns

Selection Pressure



PTI= PAMP triggered immunity

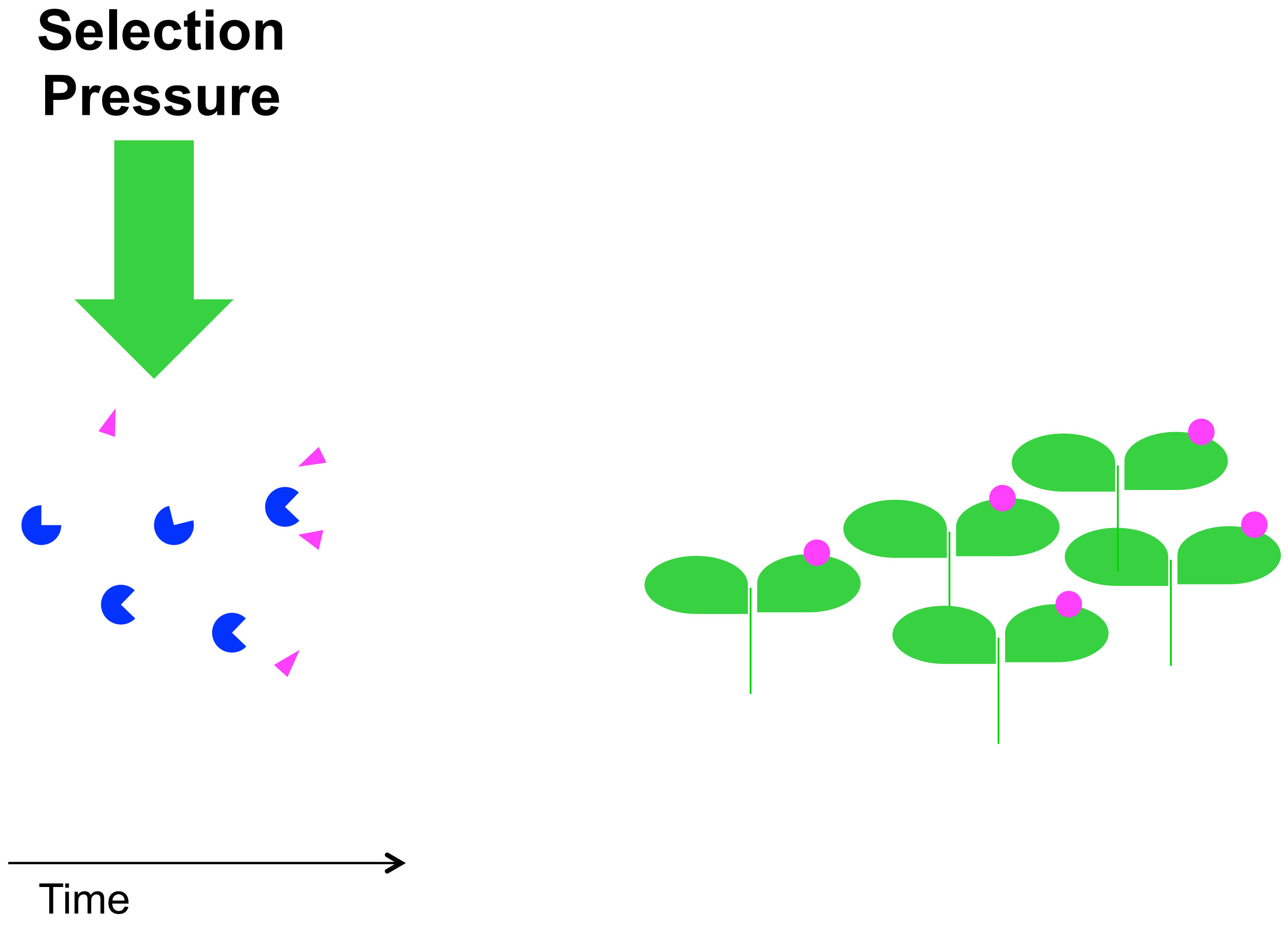




PRRs= Pattern-recognition receptor

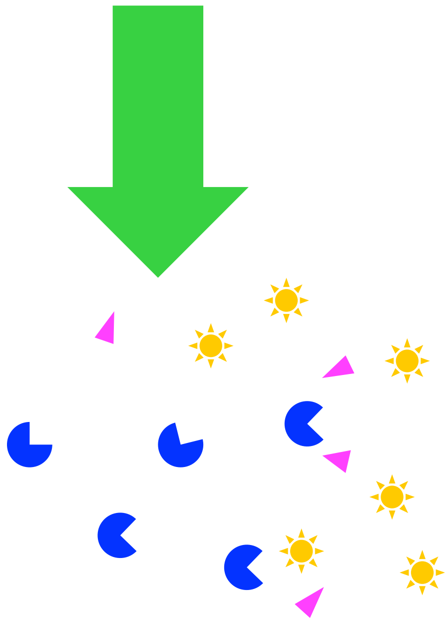
Time

Co-evolution
(Arms- race)



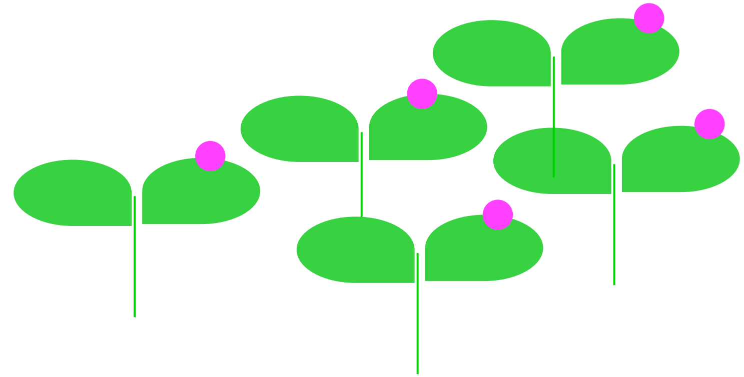
Co-evolution
(Arms- race)

Selection Pressure



 Effector= a molecule released by an organism to modify physiology of another organism

Manipulation of host defenses



Time

Co-evolution
(Arms- race)

Selection Pressure

ETS= Effector triggered susceptibility

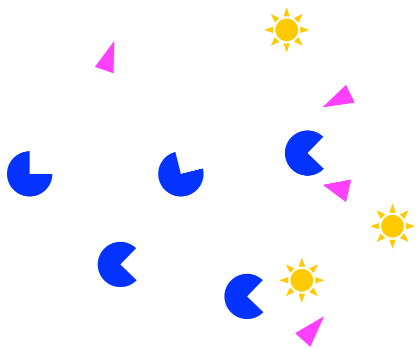
Time

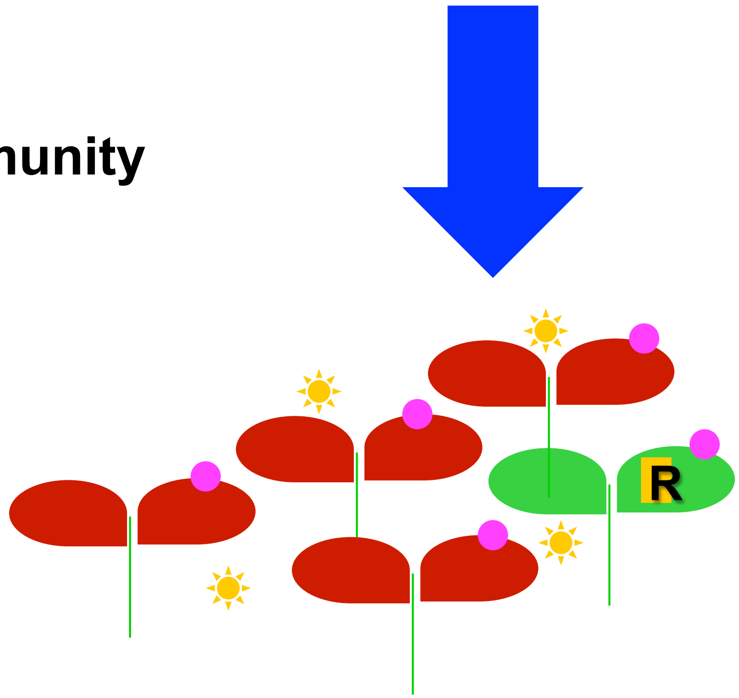
Co-evolution
(Arms- race)

Selection Pressure

R R-genes= Resistance genes encoding proteins that detect pathogens effectors

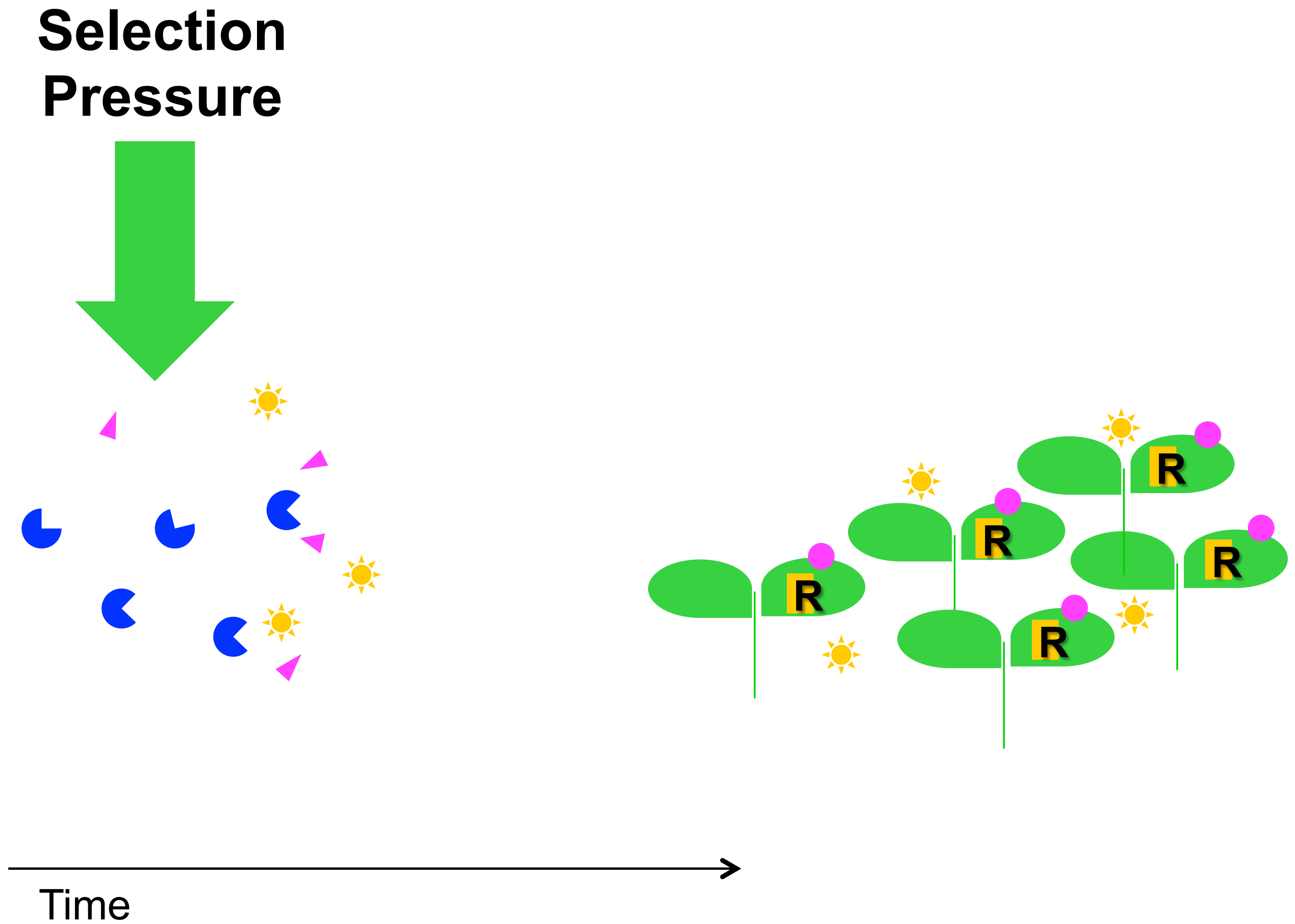
ETI= Effector triggered immunity



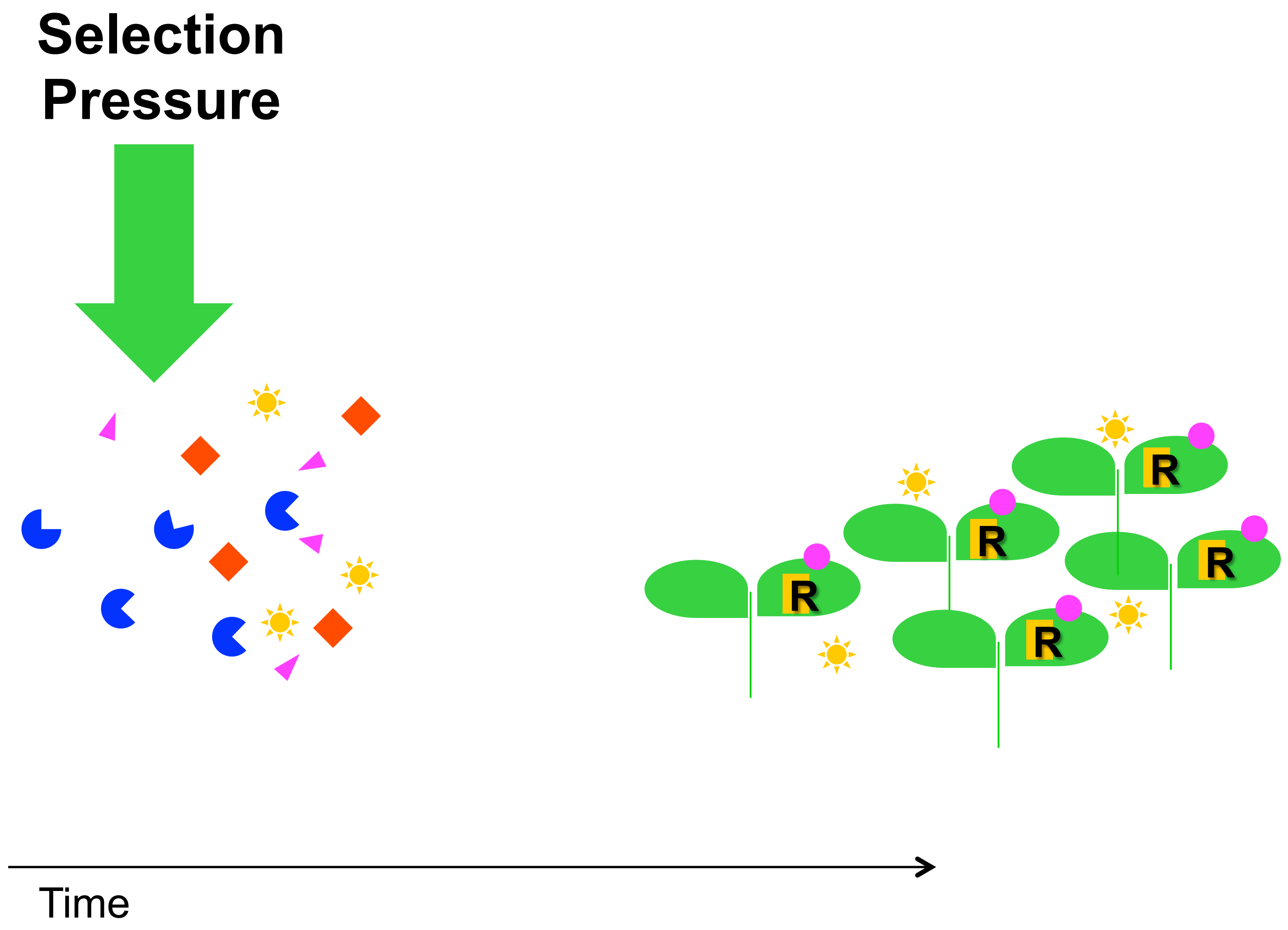


Time

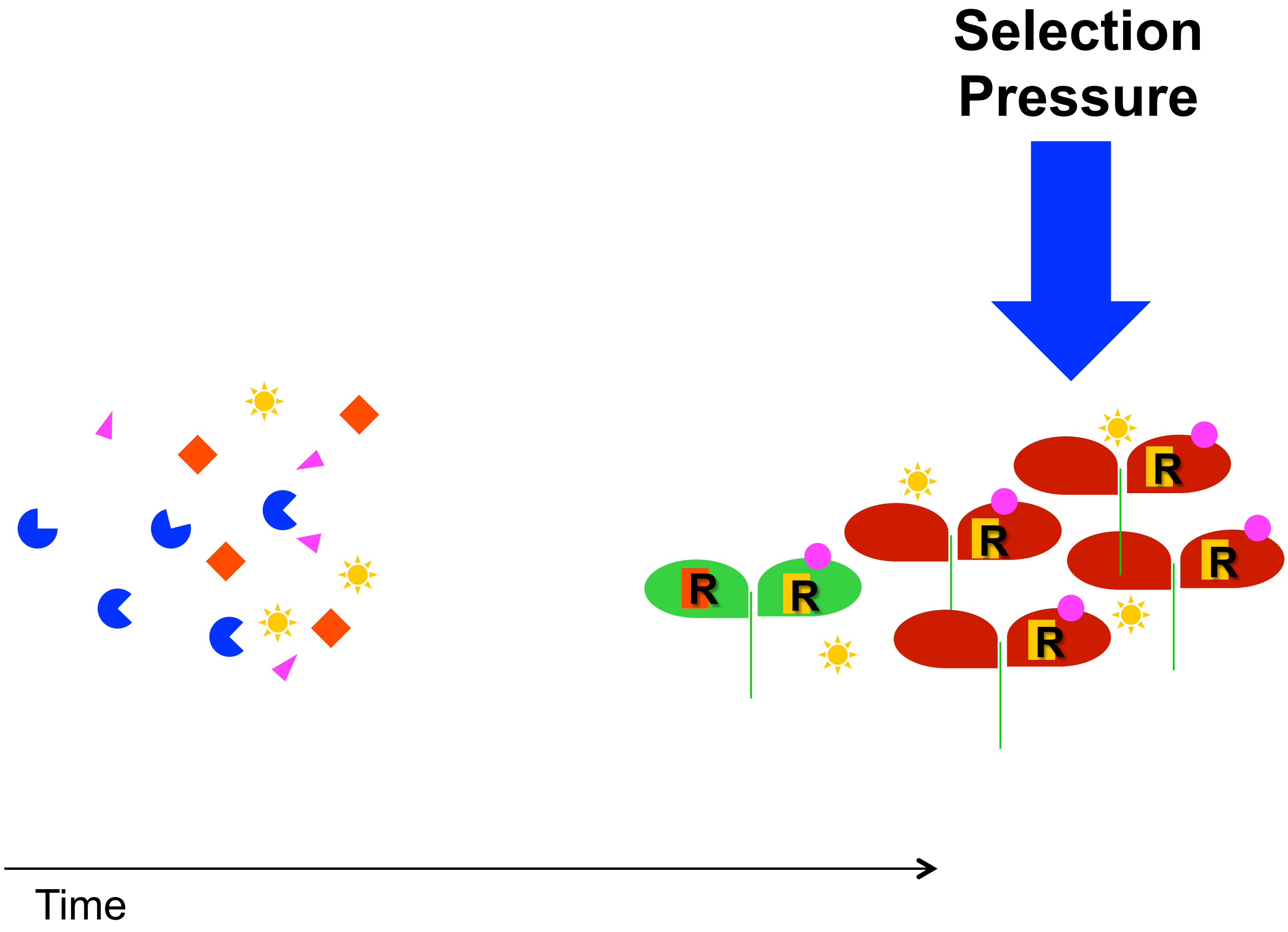
Co-evolution (Arms- race)



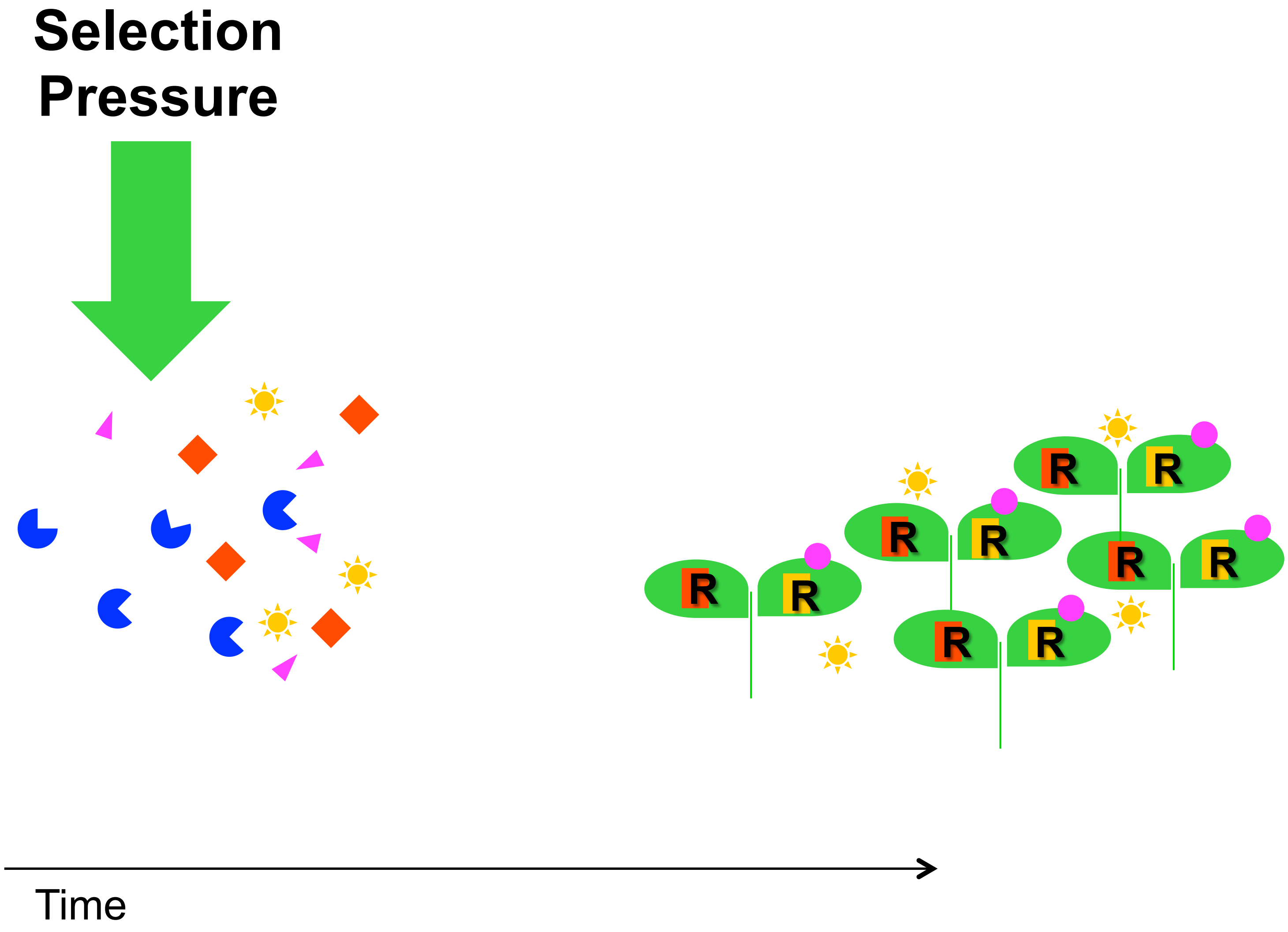
Co-evolution
(Arms- race)



Co-evolution
(Arms- race)



Co-evolution
(Arms- race)



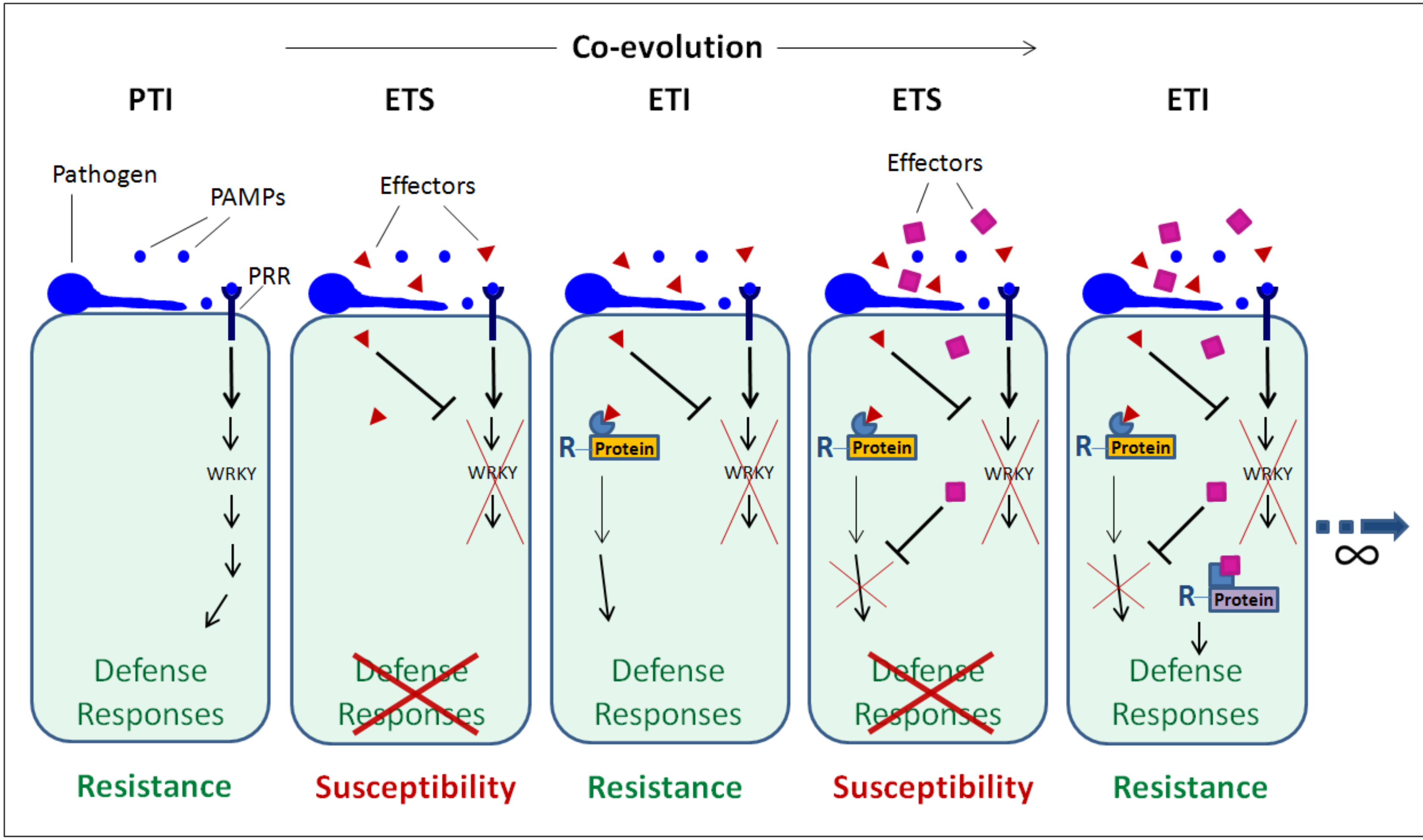
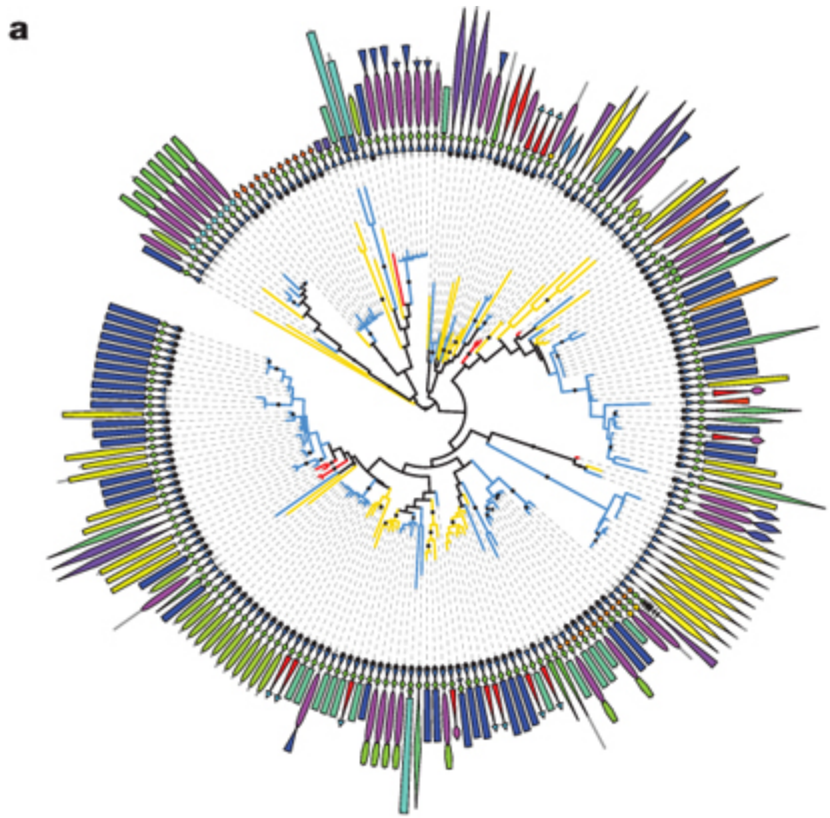
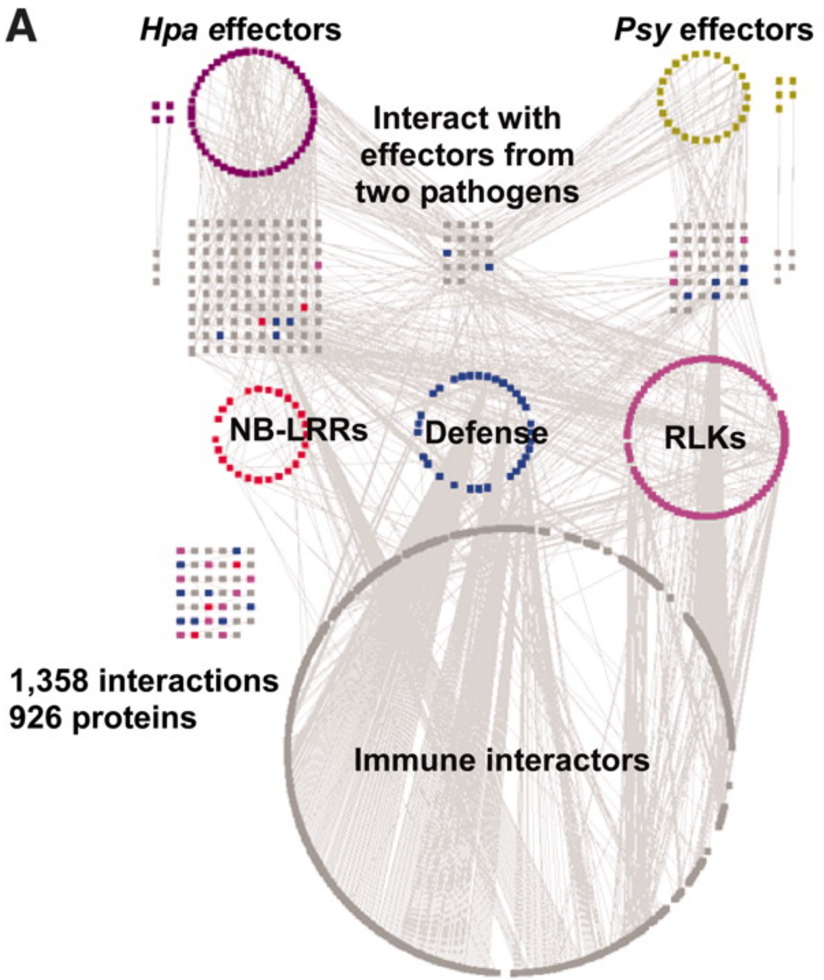

Co-evolution
PTI
ETS
ETI
ETS
ETI
Pathogen
PAMPs
PRR
Effectors
Effectors
WRKY
WRKY
WRKY
WRKY
WRKY
R
Protein
R
Protein
R
Protein
R
Protein
Defense Responses
Defense Responses
Defense Responses
Defense Responses
Defense Responses
Resistance
Susceptibility
Resistance
Susceptibility
Resistance
∞

Table 2. Number of candidate RXLR effectors identified in oomycete genomes

Species	Reference	Genome size (Mbp)	Total RXLR*
Hyaloperonospora parasitica	Washington University	75	149
Phytophthora capsici	JGI	65	420
Phytophthora infestans	Broad Institute	240	716
Phytophthora ramorum	Tyler *et al.* (2006)	65	531
Phytophthora sojae	Tyler *et al.* (2006)	95	672



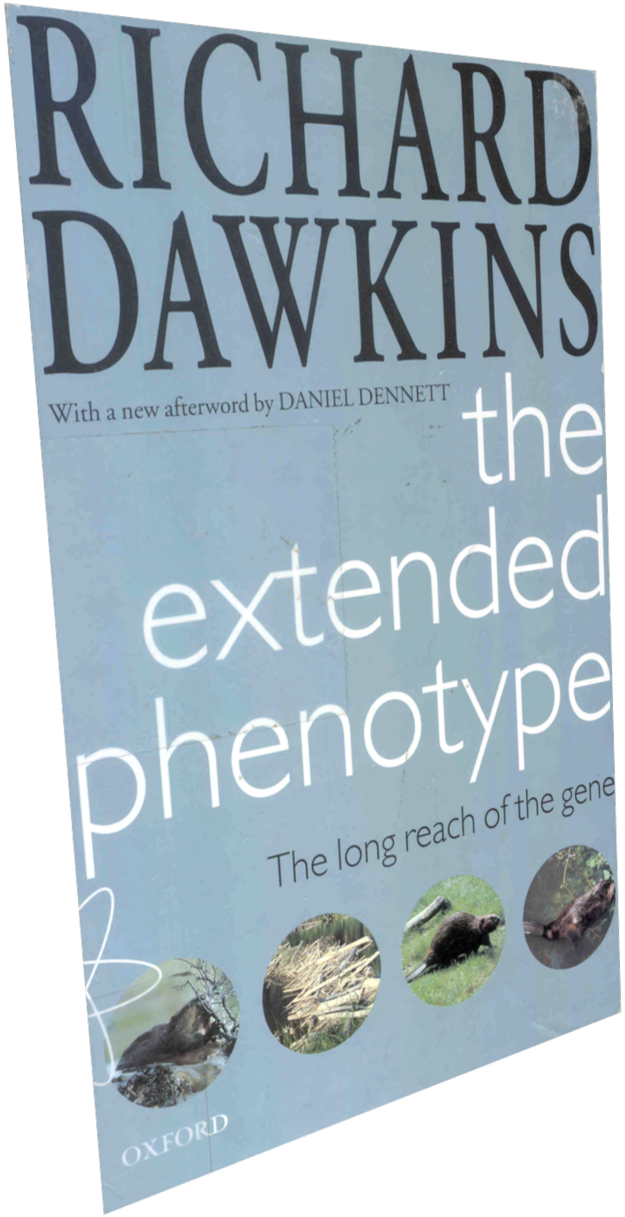
CRN family phylogeny on the basis of the conserved N-terminal sequence.



Experimentally determined plant-pathogen immune network.


super
SLOTS
0000.0034
03
00006
CREDITS
BET
WINNER PAID
25¢
RESET
PAY
TABLE
BET
ONE
BET
MAX
SPIN

1×10^{260}



"parasite genes having phenotypic expression in host bodies and behavior"

Dawkins, R; Oxford, 1982.

Xanthomonas-HD.mp4

Função

Table 1

A selection of filamentous plant pathogen effectors

Pathogen species	Effector	Localization in plant tissue[a]	Signal peptide length[b]	Positive selection	Virulence activities	Reference(s)
Blumeria graminis f. sp. *hordei*	AVRa10	Cytoplasmic	NA		Enhances infection in susceptible barley plants[c]	[29**]
	AVRk1	Cytoplasmic	NA		Enhances infection in susceptible barley plants[c]	[29**]
Cladosporium fulvum	Avr2	Apoplastic	20		Cysteine protease inhibitor; inhibits tomato Rcr3[c]	[43]
	Avr4	Apoplastic	18		Contains CBM14 chitin binding domain; protects fungal cell walls from hydrolysis by plant chitinases[c]	[44]
	Avr9	Apoplastic	23		Structural similarity to cystine knot carboxypeptidase inhibitor[d]	[57]
Fusarium oxysporum f. sp. *lycopersici*	SIX1	Apoplastic (xylem)	21			[49]
Hyaloperonospora parasitica	ATR1	Cytoplasmic	15	Yes		[30]
	ATR13	Cytoplasmic	18	Yes		[52]
Leptosphaeria maculans	AvrLm1	Probably cytoplasmic	22			[24]
Magnaporthe oryzae	Avr-Pita	Cytoplasmic	16		Metalloprotease[d]	[25]
Melampsora lini	AvrL567	Cytoplasmic	23	Yes		[16,18**]
	AvrM	Cytoplasmic	28	Yes		[17*]
	AvrP123	Cytoplasmic	23		Kazal-like protease inhibitor[d]	[17*]
	AvrP4	Cytoplasmic	28	Yes		[17*]
Phytophthora infestans	Avr3a	Cytoplasmic	21	Yes	Cell death suppressor[c]	[33**,50]
	CRN1	Cytoplasmic	17		Elicits cell death in host plants[c]	[31]
	CRN2	Cytoplasmic	22		Elicits cell death in host plants[c]	[31]
	CRN8	Cytoplasmic	17		Similarity to RD kinase[d]; elicits cell death in host plants[c]	[40], C Cakir *et al.*, unpublished
	EPI1	Apoplastic	16		Kazal-like serine protease inhibitor; inhibits tomato P69B[c]	[45]
	EPI10	Apoplastic	21		Kazal-like serine protease inhibitor; inhibits tomato P69B[c]	[46]
	EPIC1	Apoplastic	21	Yes	Cystatin-like cysteine protease inhibitor[d]	[47]
	EPIC2B	Apoplastic	21	Yes	Cystatin-like cysteine protease inhibitor; inhibits tomato PIP1[c]	[47]
Phytophthora sojae	Avr1b-1	Cytoplasmic	21	Yes		[58]
Rhynchosporium secalis	NIP1	Apoplastic	20	Yes	Toxin; elicits necrosis in host plants[c]	[54]
Uromyces fabae	*Uf*-RTP1	Cytoplasmic	19		Localizes to host nucleus[c]	[19**]

[a] Cytoplasmic vs. apoplastic effectors based on the classification described in the text and in Reference [w3].

[b] Length in amino acids, based on SignalP v2.0-NN (http://www.cbs.dtu.dk/services/SignalP-2.0); NA, not applicable.

[c] Evidence is based on wet lab experimental data.

[d] Evidence is based on computational analyses.

RESEARCH ARTICLE

Major Transcriptome Reprogramming Underlies Floral Mimicry Induced by the Rust Fungus *Puccinia monoica* in *Boechera stricta*

Liliana M. Cano, Sylvain Raffaele, Riston H. Haugen, Diane G. O. Saunders, Lauriebeth Leonelli, Dan MacLean, Saskia A. Hogenhout, Sophien Kamoun

Published: September 17, 2013 • DOI: 10.1371/journal.pone.0075293

Abstract

Puccinia monoica is a spectacular plant parasitic rust fungus that triggers the formation of flower-like structures (pseudoflowers) in its Brassicaceae host plant *Boechera stricta*. Pseudoflowers mimic in shape, color, nectar and scent co-occurring and unrelated flowers such as buttercups. They act to attract insects thereby aiding spore dispersal and sexual reproduction of the rust fungus. Although much ecological research has been performed on *P. monoica*-induced pseudoflowers, this system has yet to be investigated at the molecular or genomic level. To date, the molecular alterations underlying the development of pseudoflowers and the genes involved have not been described. To address this, we performed gene

Figure 1. Illustration of floral mimicry produced by the pseudoflower-forming rust fungus *Puccinia monoica*.

Abstract

Puccinia monoica is a spectacular plant parasitic rust fungus that triggers the formation of flower-like structures (pseudoflowers) in its Brassicaceae host plant *Boechera stricta*. Pseudoflowers mimic in shape, color, nectar and scent co-occurring and unrelated flowers such as buttercups. They act to attract insects thereby aiding spore dispersal and sexual reproduction of the rust fungus. Although much ecological research has been performed on *P. monoica*-induced pseudoflowers, this system has yet to be investigated at the molecular or genomic level. To date, the molecular alterations underlying the development of pseudoflowers and the genes involved have not been described. To address this, we performed gene expression profiling to reveal 256 plant biological processes that are significantly altered in pseudoflowers. Among these biological processes, plant genes involved in cell fate specification, regulation of transcription, reproduction, floral organ development, anthocyanin (major floral pigments) and terpenoid biosynthesis (major floral volatile compounds) were down-regulated in pseudoflowers. In contrast, plant genes involved in shoot, cotyledon and leaf development, carbohydrate transport, wax biosynthesis, cutin transport and L-phenylalanine metabolism (pathway that results in phenylethanol and phenylacetaldehyde volatile production) were up-regulated. These findings point to an extensive reprogramming of host genes by the rust pathogen to induce floral mimicry. We also highlight 31 differentially regulated plant genes that are enriched in the biological processes mentioned above, and are potentially involved in the formation of pseudoflowers. This work illustrates the complex perturbations induced by rust pathogens in their host plants, and provides a starting point for understanding the molecular mechanisms of pathogen-induced floral mimicry.

Zombies

Horrifying Fungus Creates Zombie Ants

Added by James Fenner *on September 14, 2013.*
Saved under James Fenner, Science, Zombie ants

Article Talk Read Edit View h

Ophiocordyceps unilateralis

From Wikipedia, the free encyclopedia

Ophiocordyceps unilateralis is an entomopathogenic fungus predominantly found in tropical forest ecosystems. In order to increase its own fitness *O. unilateralis* utilizes the evolutionary trait of an extended phenotype to manipulate the behavioral patterns of an infected formicidae, specifically *Camponotus leonardi* of the tribe of campotini. The infected ants leave their canopy nest and foraging trails, heading for the forest floor in search of an area with a temperature and humidity level that is suitable for fungal growth. The infected ant will then use its mandible to affix themselves to a major vein on the underside of a leaf and eventually die.[2]

Duas principais estratégias dos patógenos:

1- Impedir / Driblar o reconhecimento da infecção

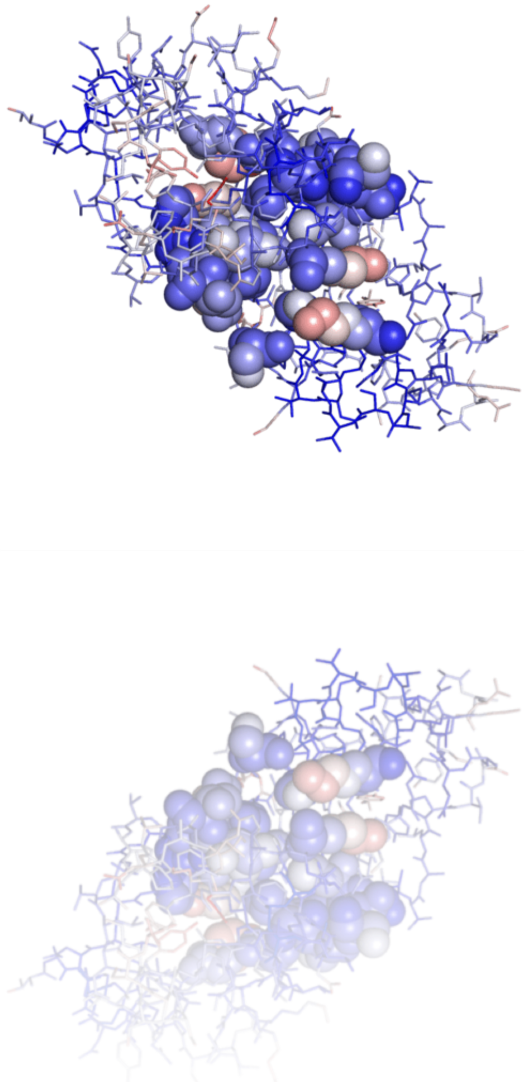
2- penetrar e crescer rápida e exponencialmente nos tecidos da planta

Quais seriam então as nossas estratégias para impedir o desenvolvimento de doenças?

1- Facilitar o reconhecimento da infecção

2- Aumentar a capacidade e rapidez da resposta das plantas ao ataque

- Indução de resistência,
- controle biológico,
- priming,
- manipulação de efetores e PAMPs,
- plantas transgênicas

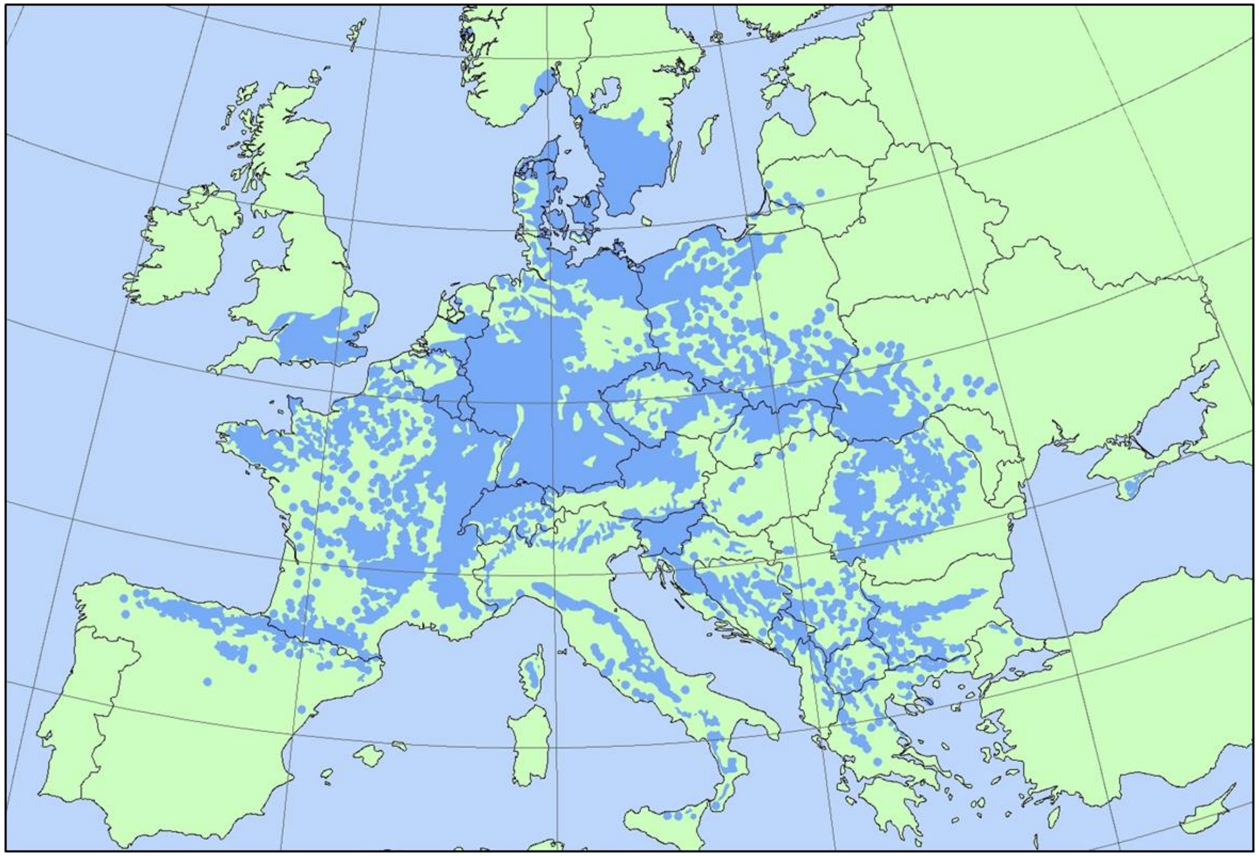


α-plurivorin (elicitin) on

Phytophthora plurivora Vs Fagus sylvatica

Fagus sylvatica – Beech - Faia européia „Mother of forests“

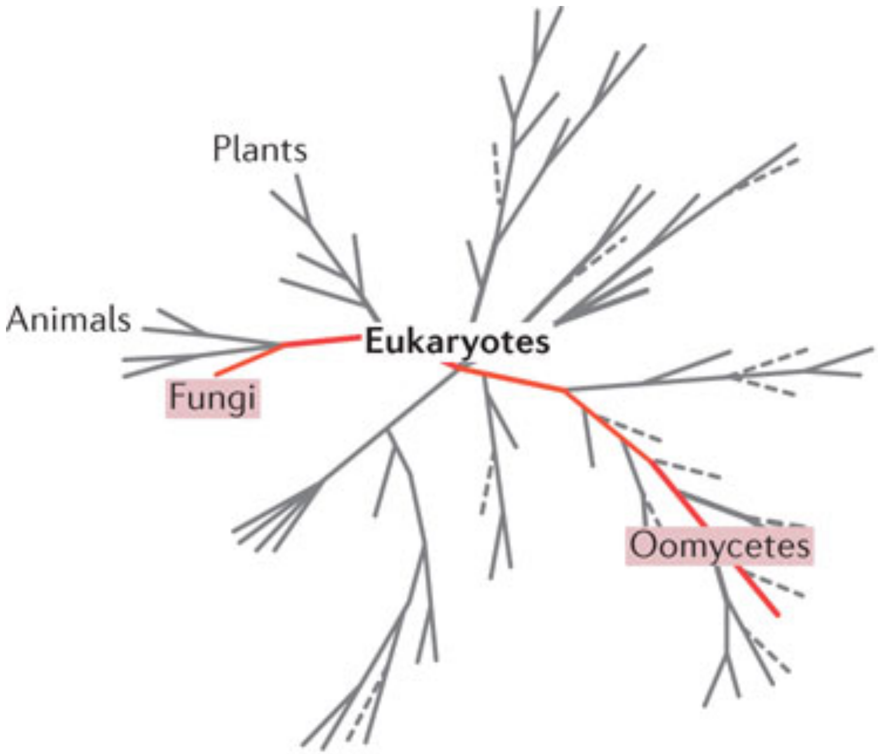
Fagus sylvatica – Distribution map



Spike in the mortality of trees in the last decade.

- Climate change
- Phytophthora infection

Oomycetes - Phytophthora

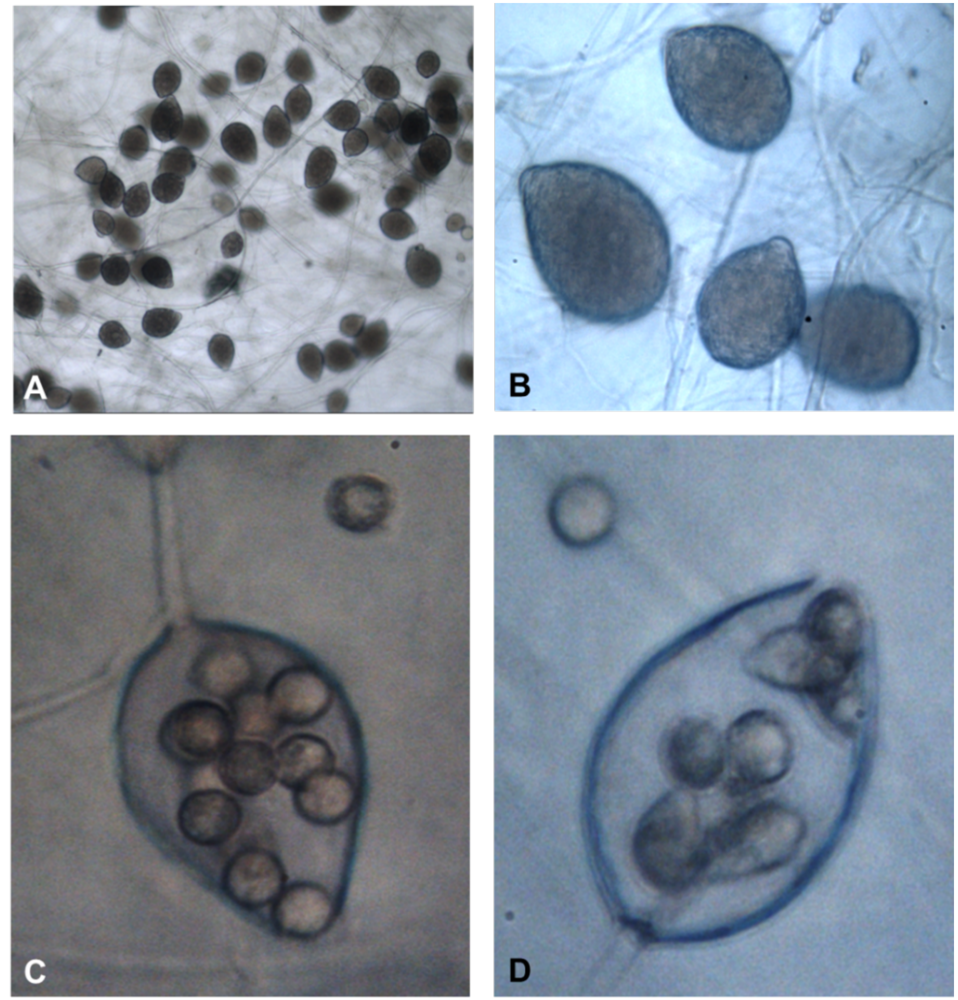


Nature Reviews | Microbiology

Bats are not birds
Dolphins are not fish
Oomycetes are not fungi!

Phytophthora plurivora

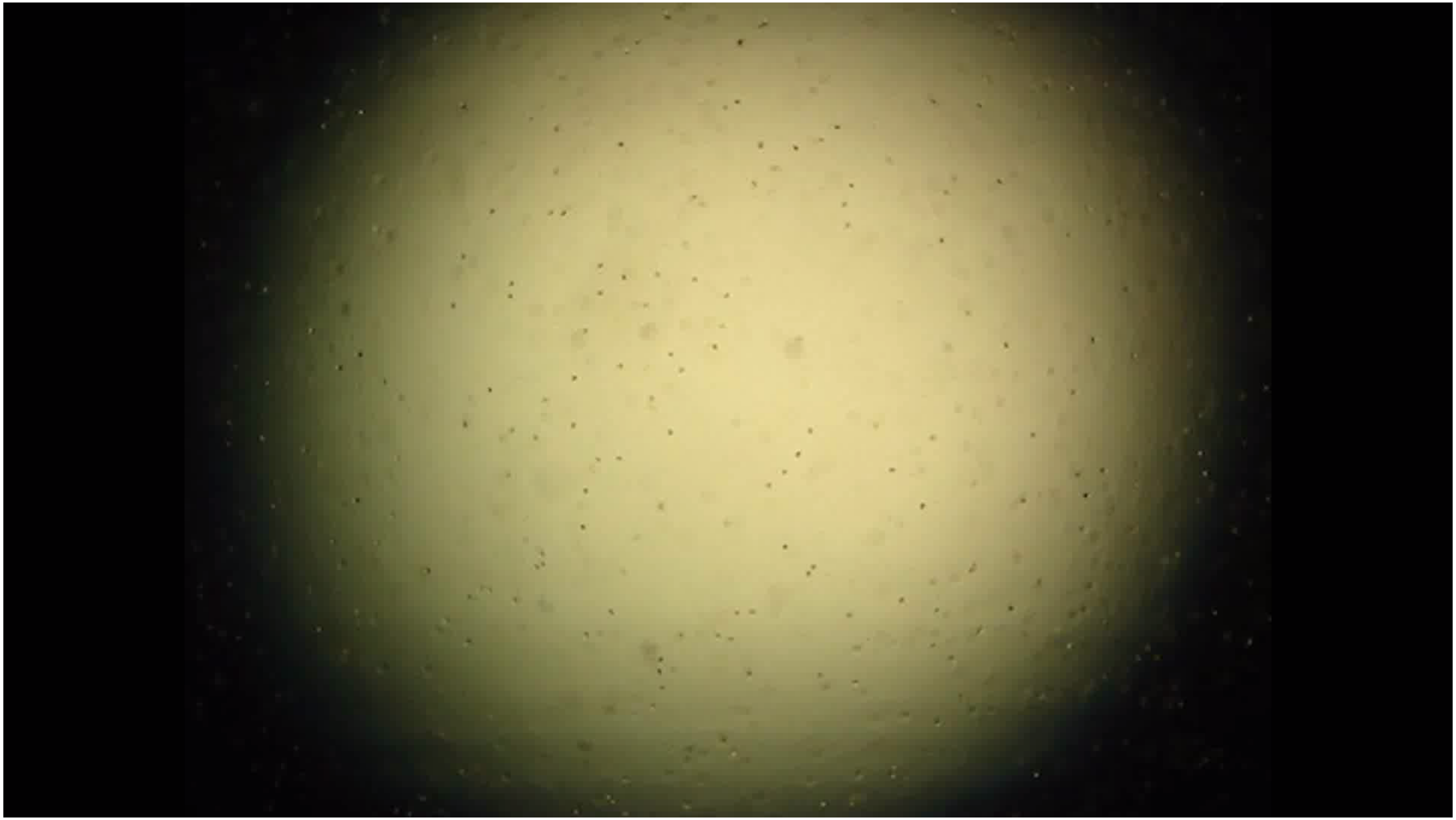
- Broad host range
- World-wide distribution
- Very aggressive soil born pathogen attacking roots
- motile zoospores



Sporangia releasing zoospores

Attraction to Beech root exudates: http://www.youtube.com/watch?v=F4sITLkhwuY

Zoospore attraction to root exudates.wmv

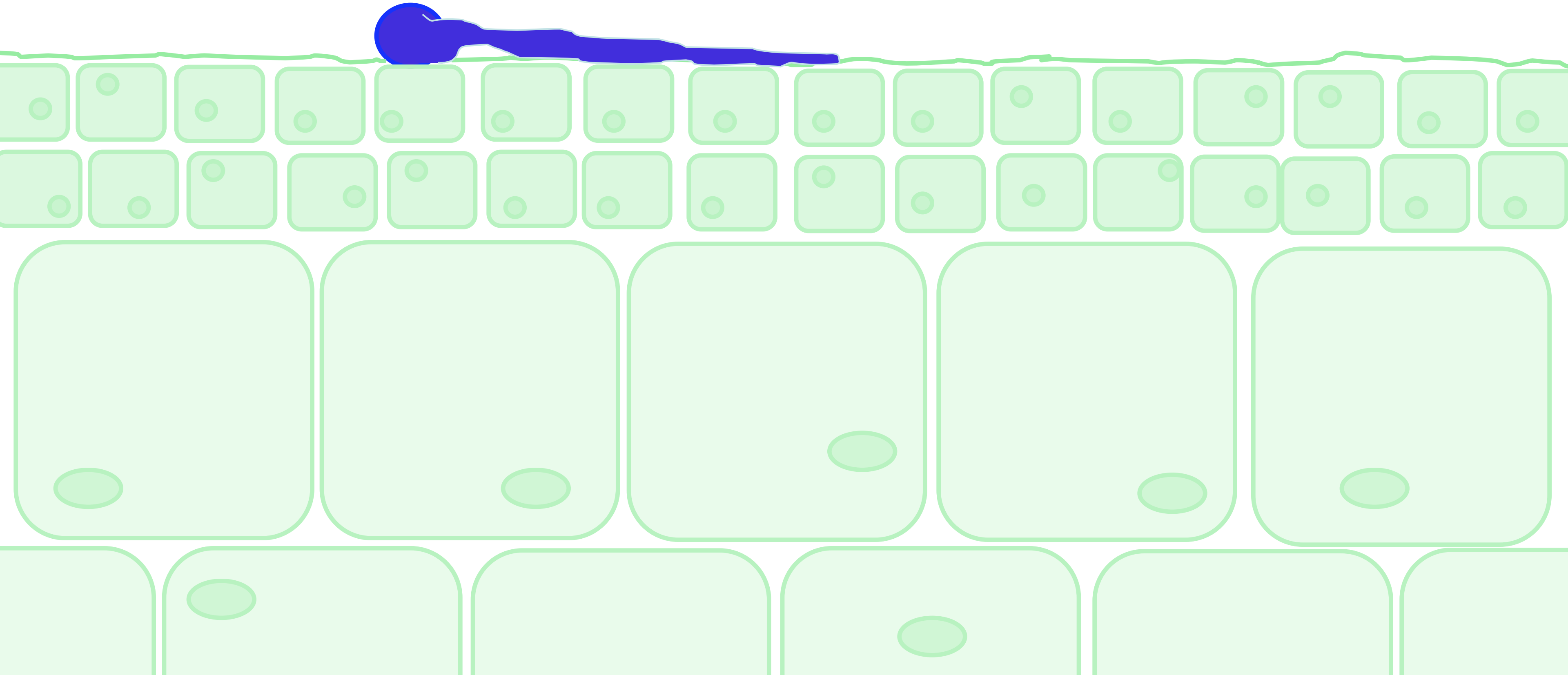


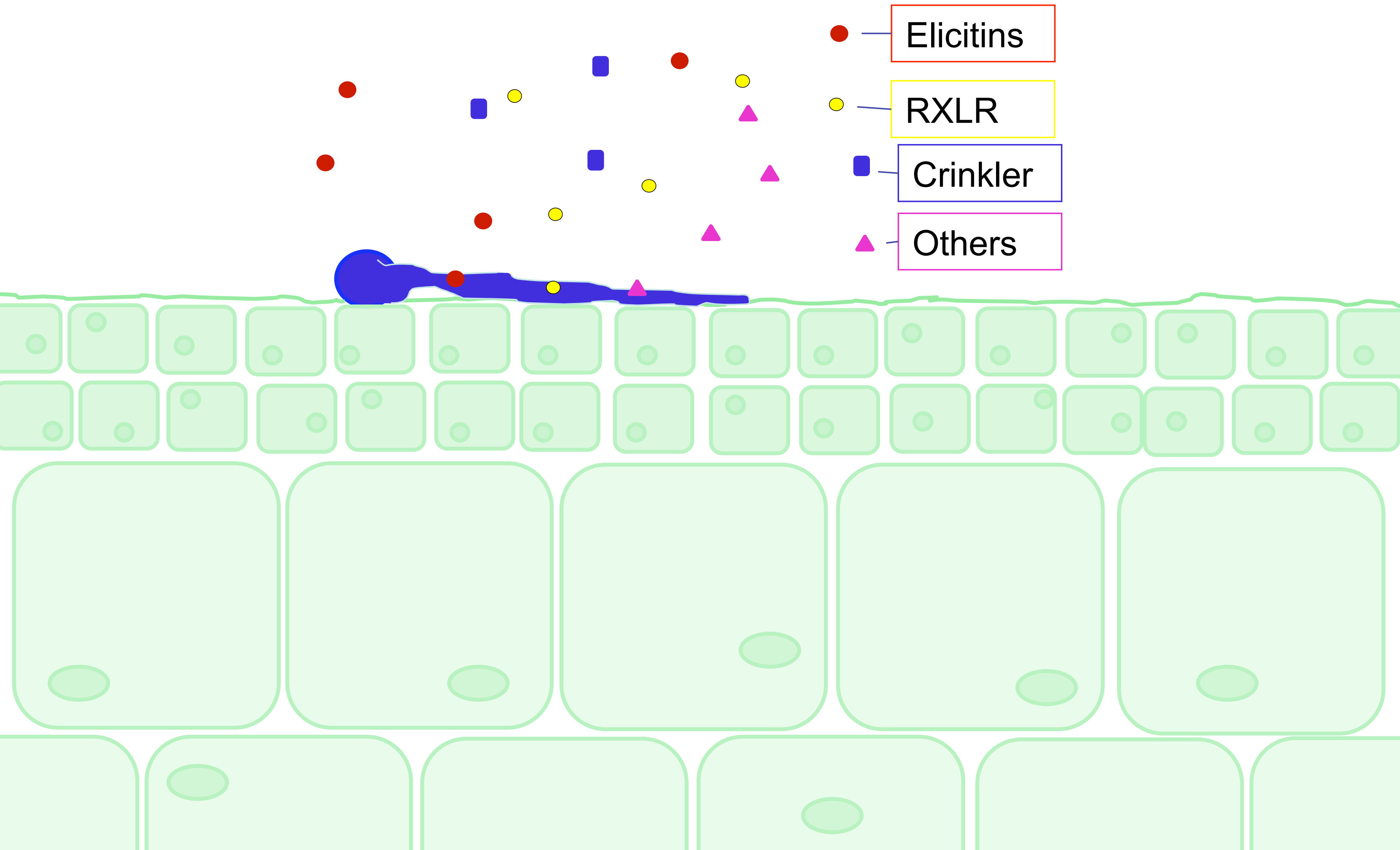
Attacking Beech root piece: http://www.youtube.com/watch?v=_vhlVak2z-U

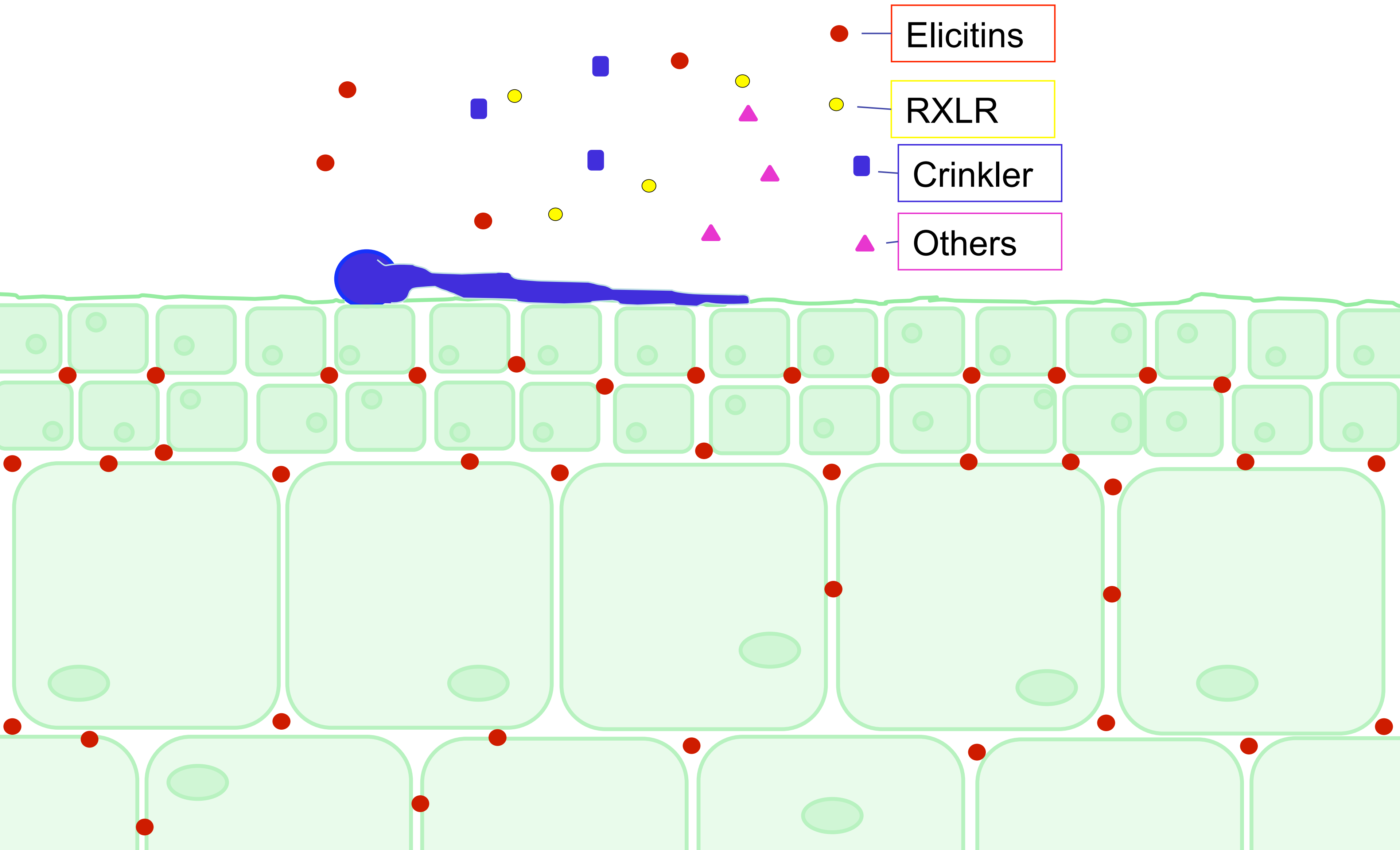
Micélio em raízes

Controle

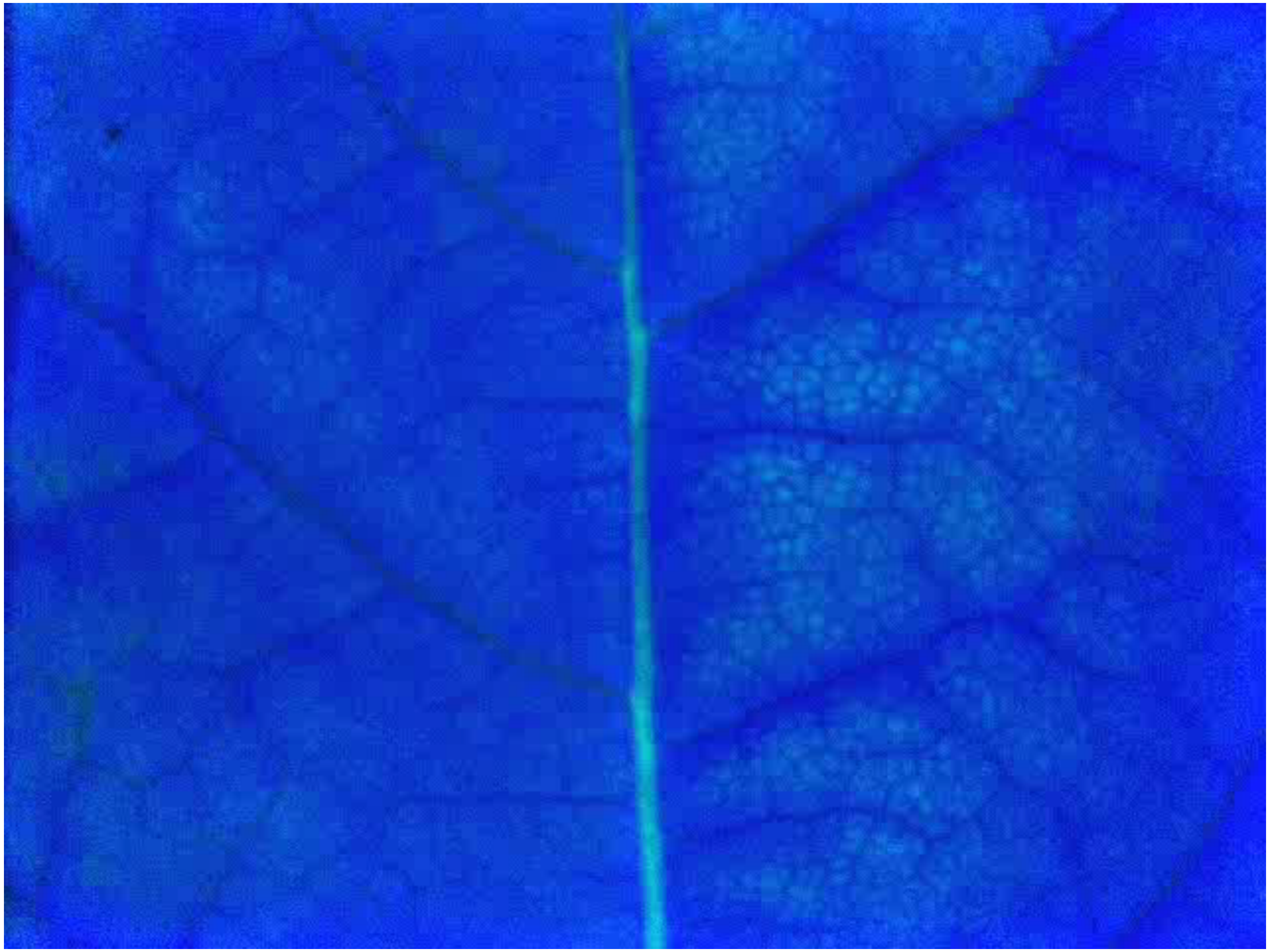
Inoculado



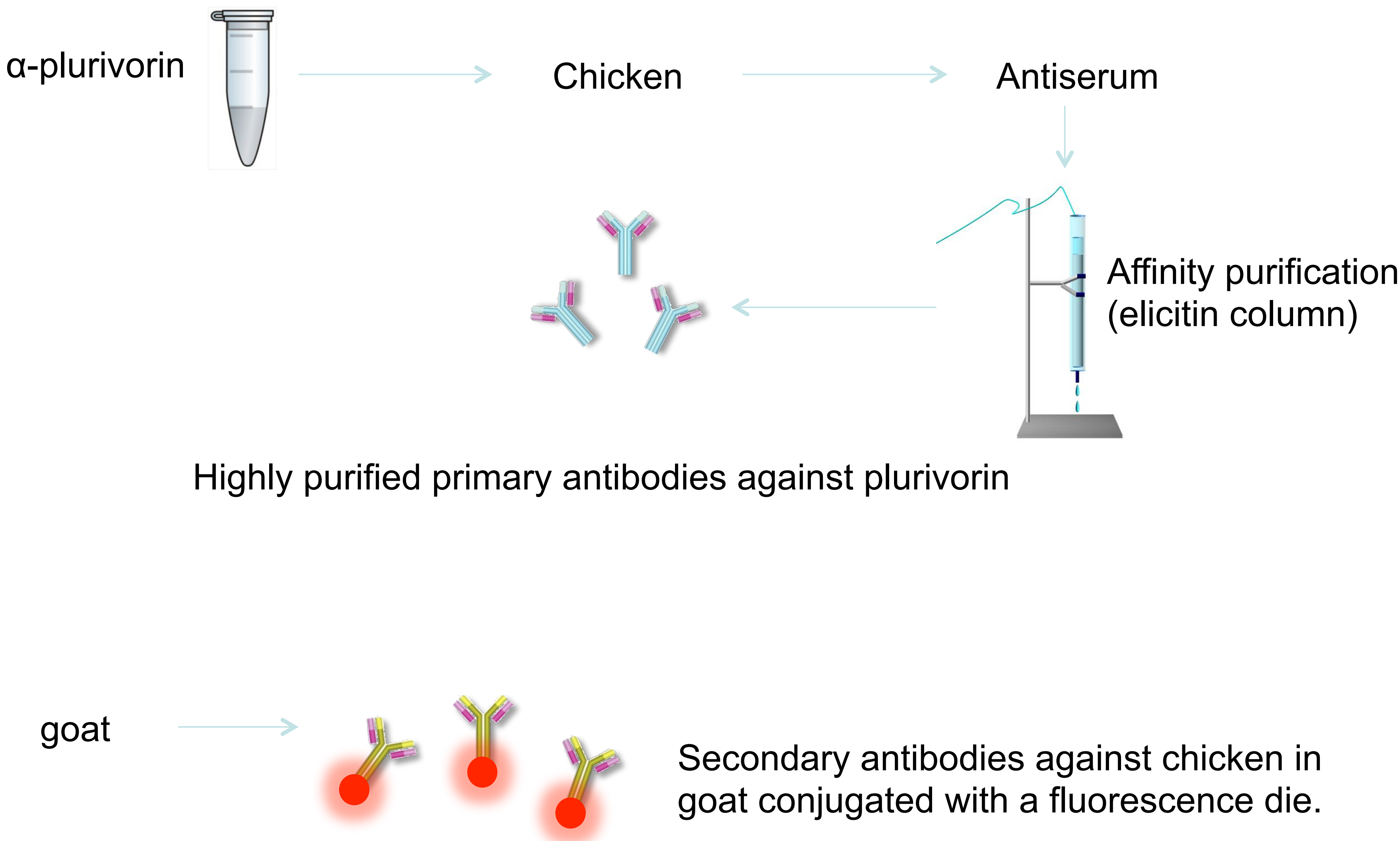

Elicitins
RXLR
Crinkler
Others

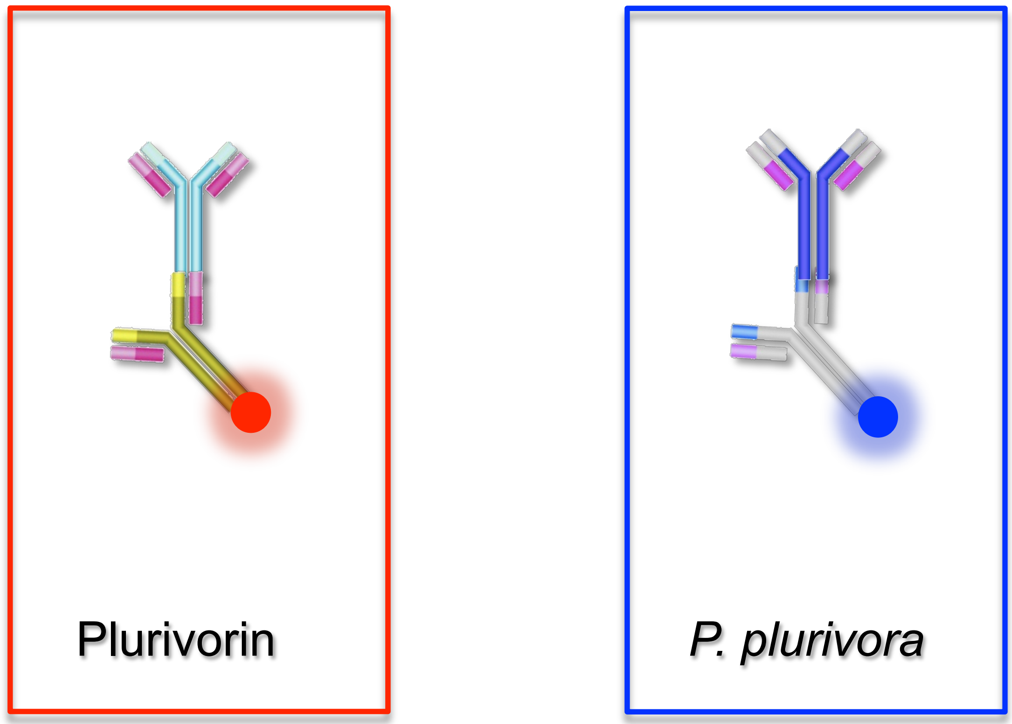

Elicitins
RXLR
Crinkler
Others

Video: Chlorophyll fluorescence of a *P. plurivora*-infected *F. sylvatica* seedling.

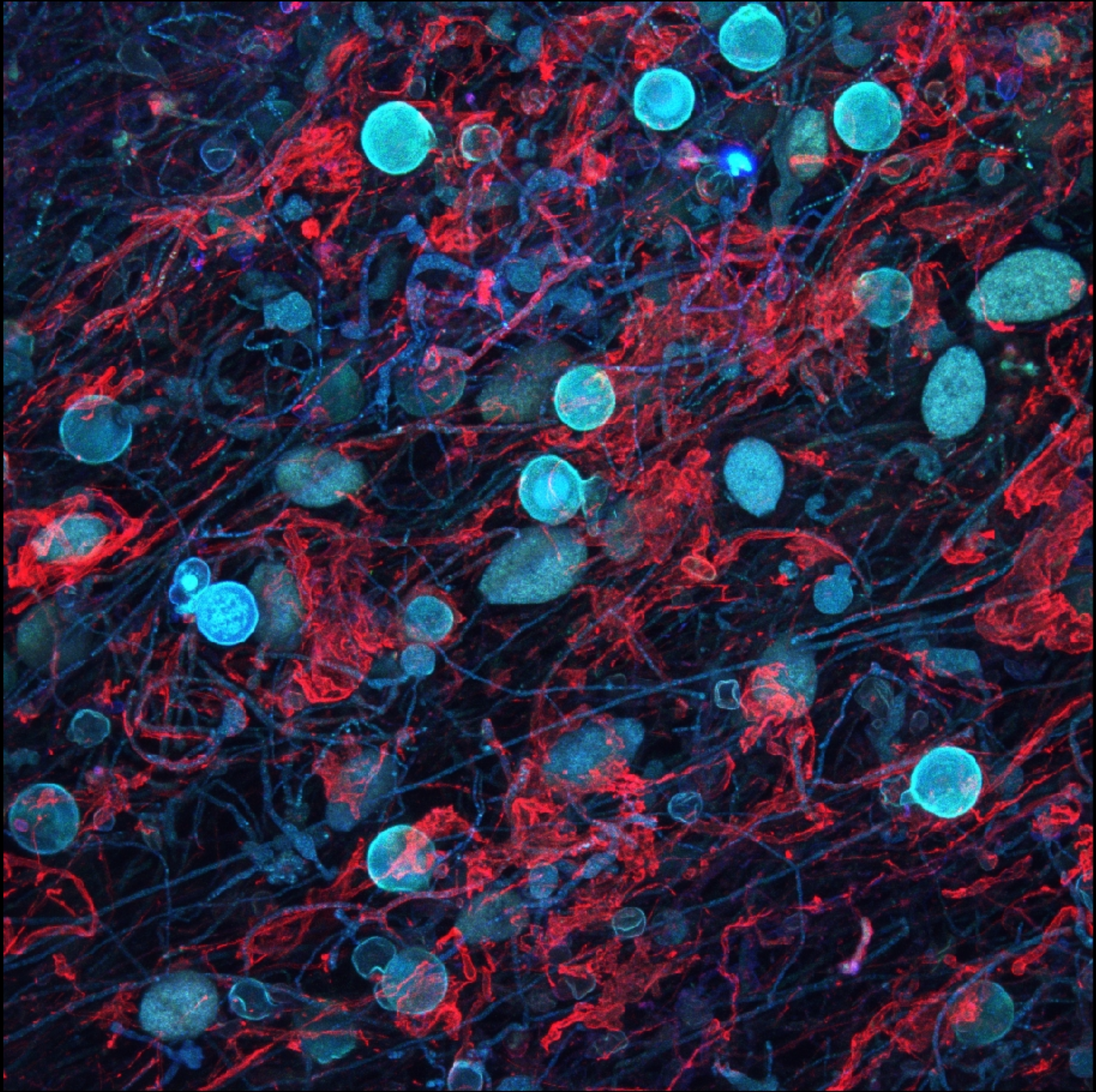


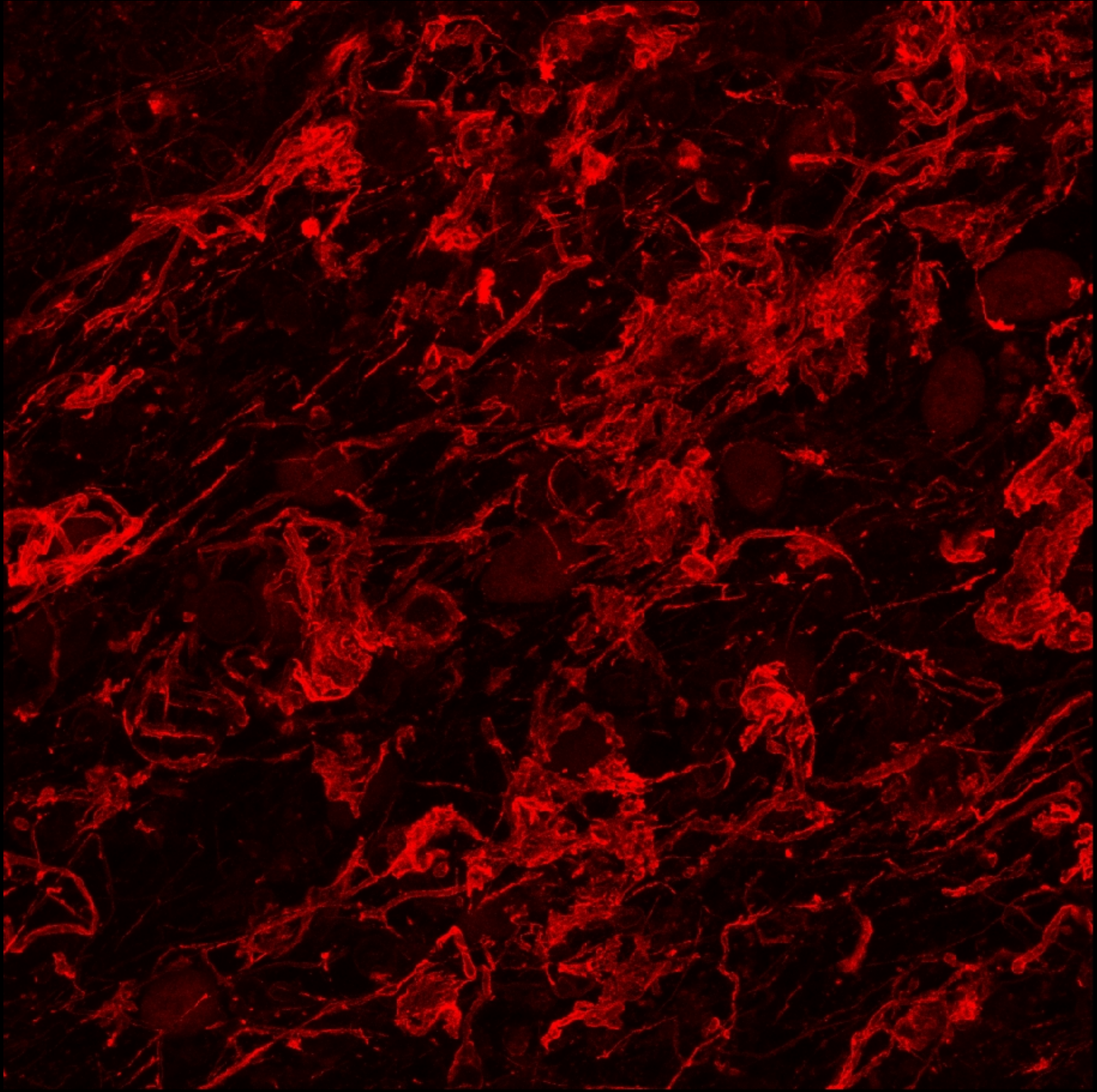
Imaging Pam Yield analyzer

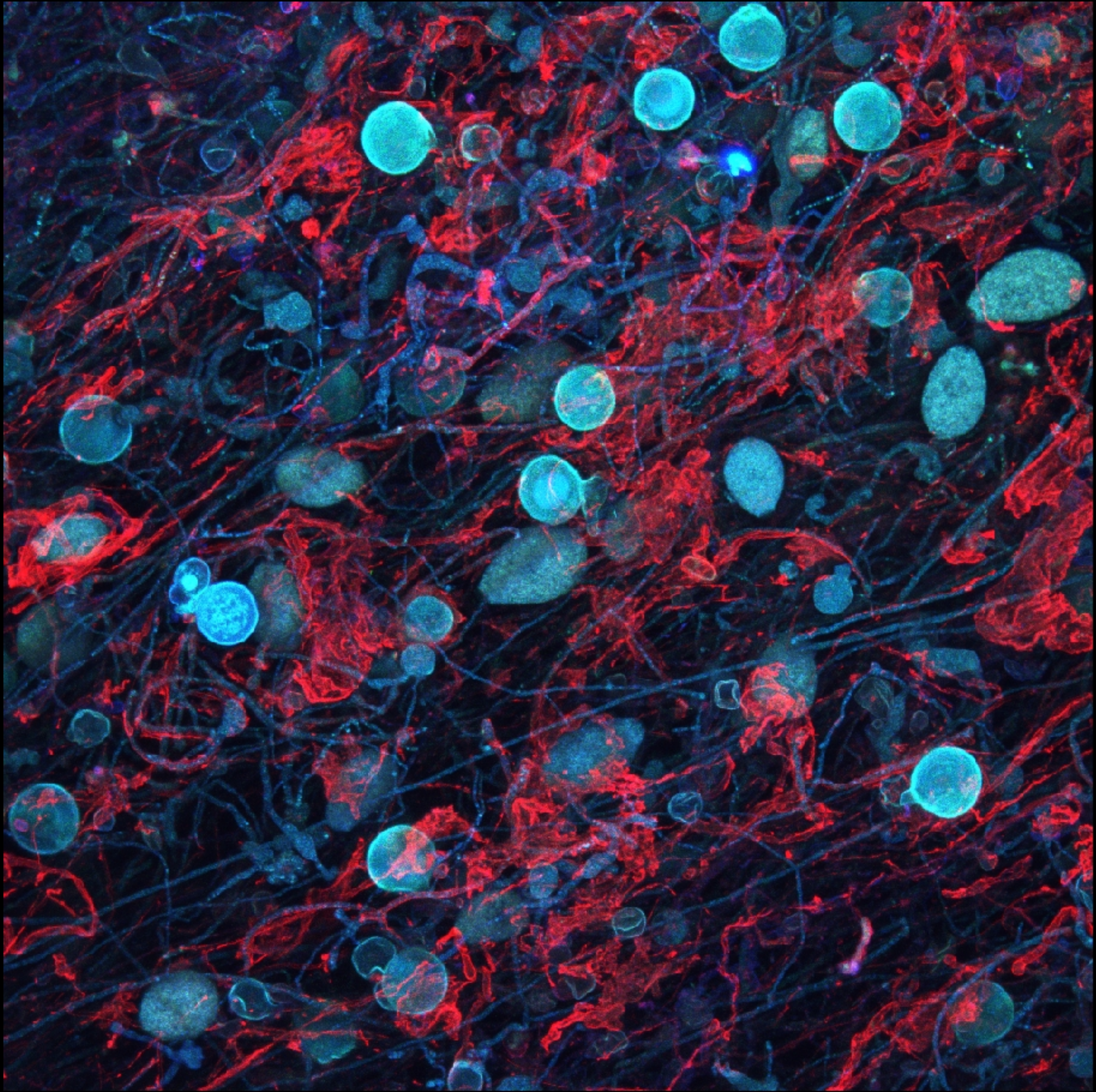

α-plurivorin
Chicken
Antiserum
Affinity purification
(elicitin column)
Highly purified primary antibodies against plurivorin
goat
Secondary antibodies against chicken in
goat conjugated with a fluorescence die.

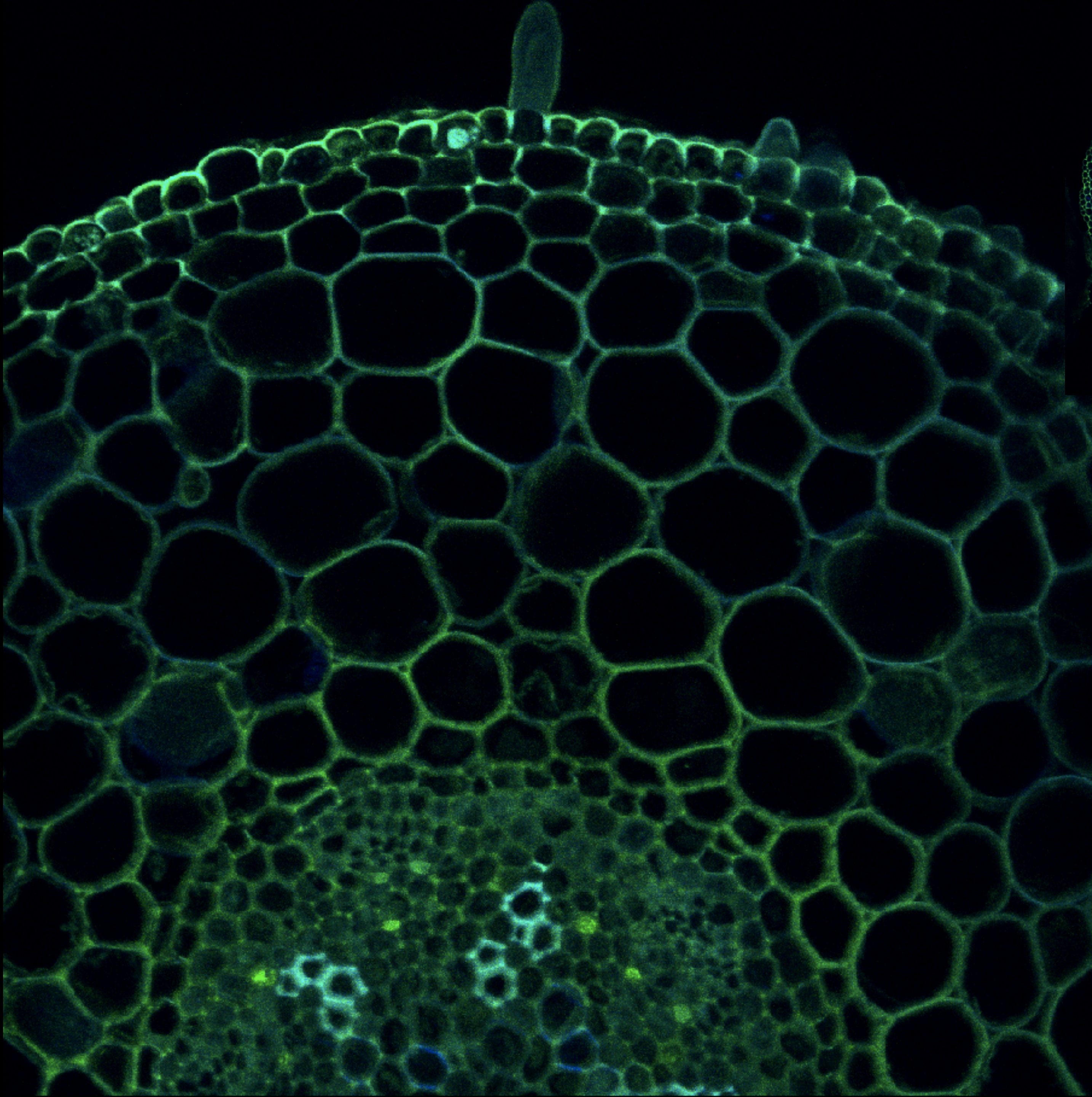

Plurivorin
P. plurivora

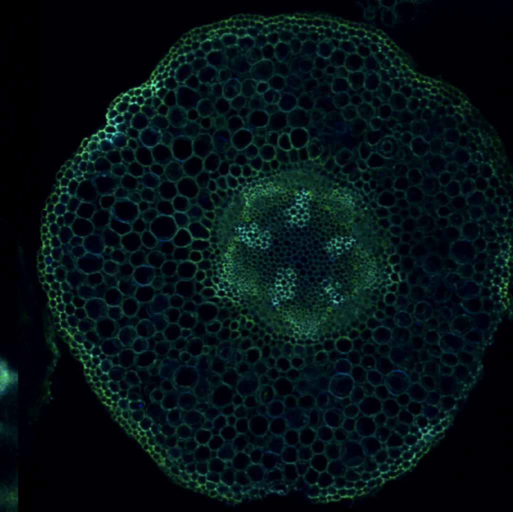
In vitro





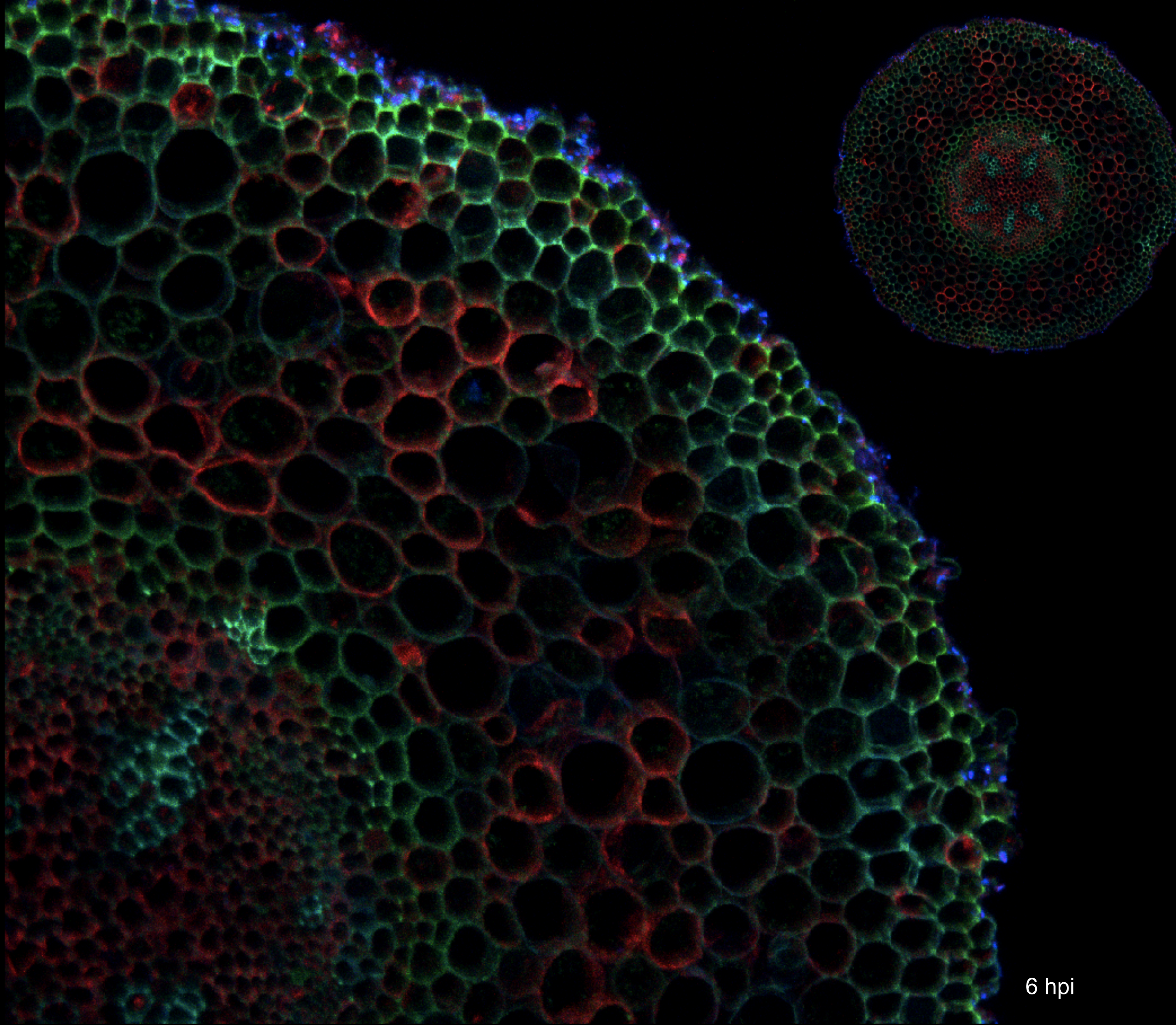


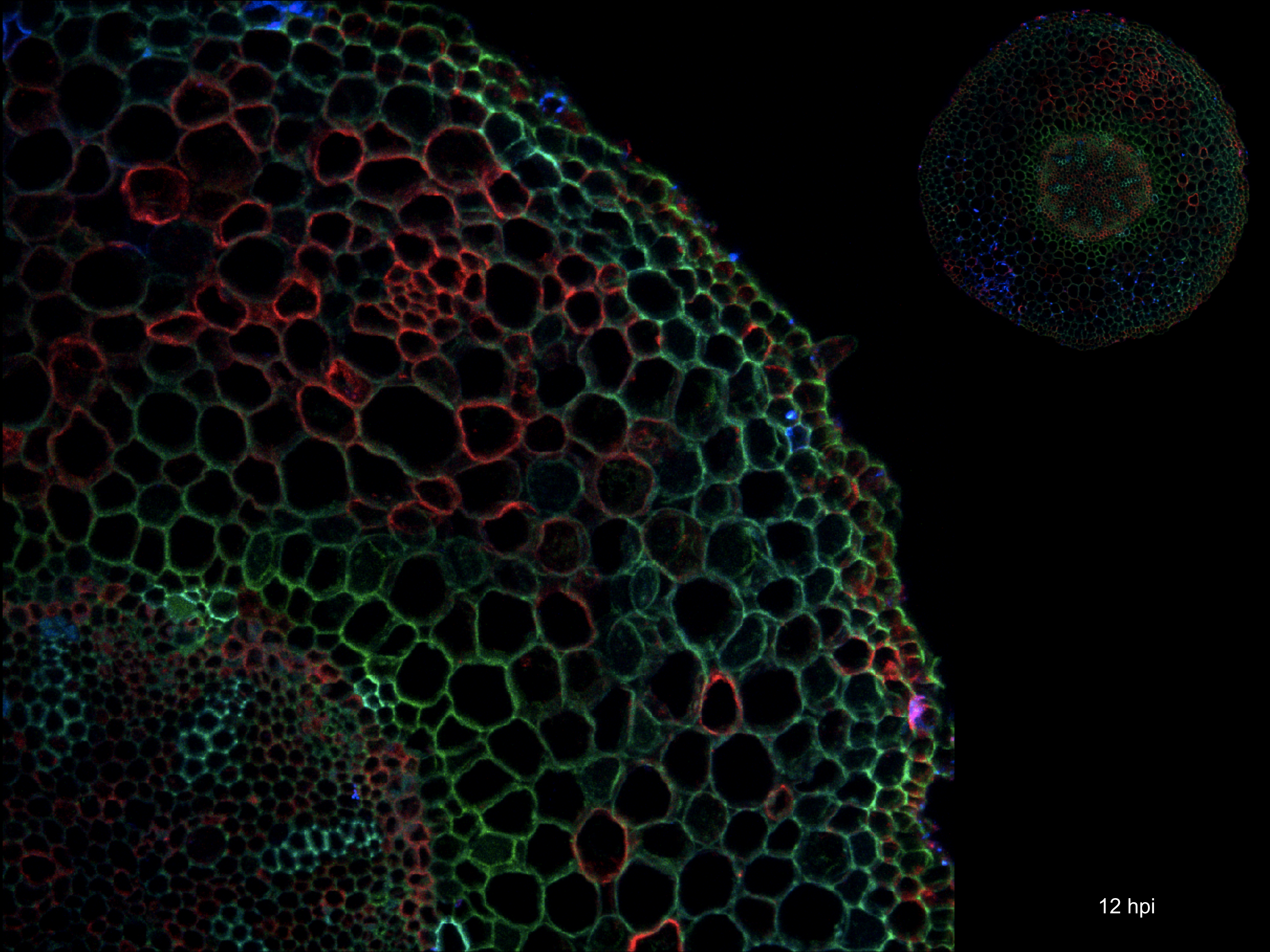


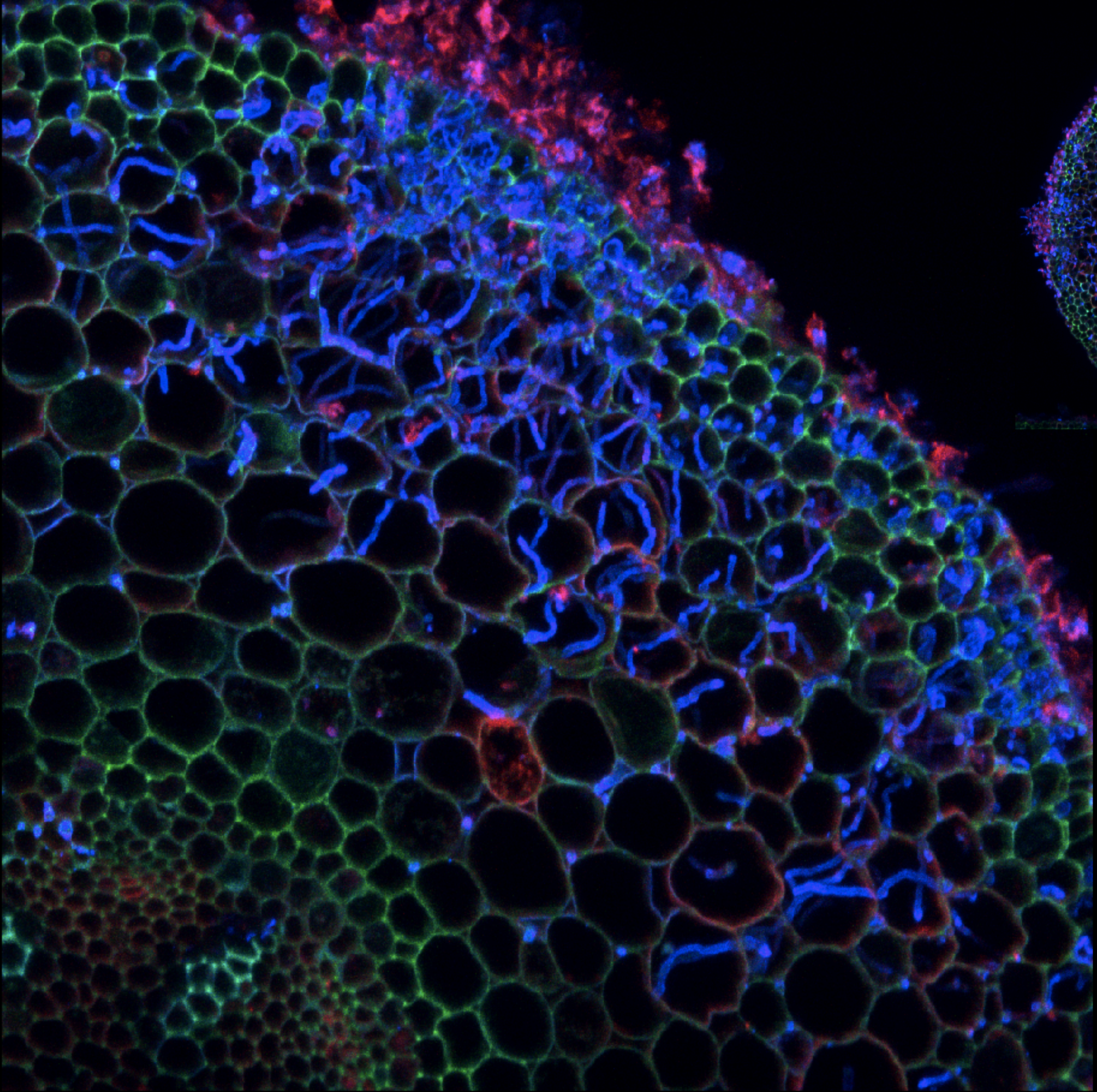


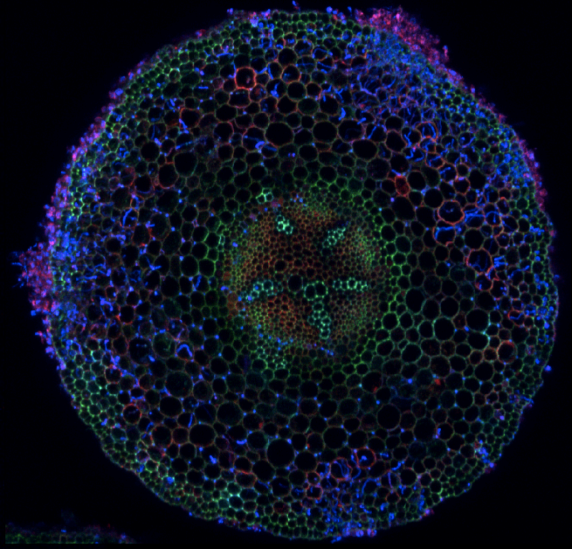
Control

0 hpi

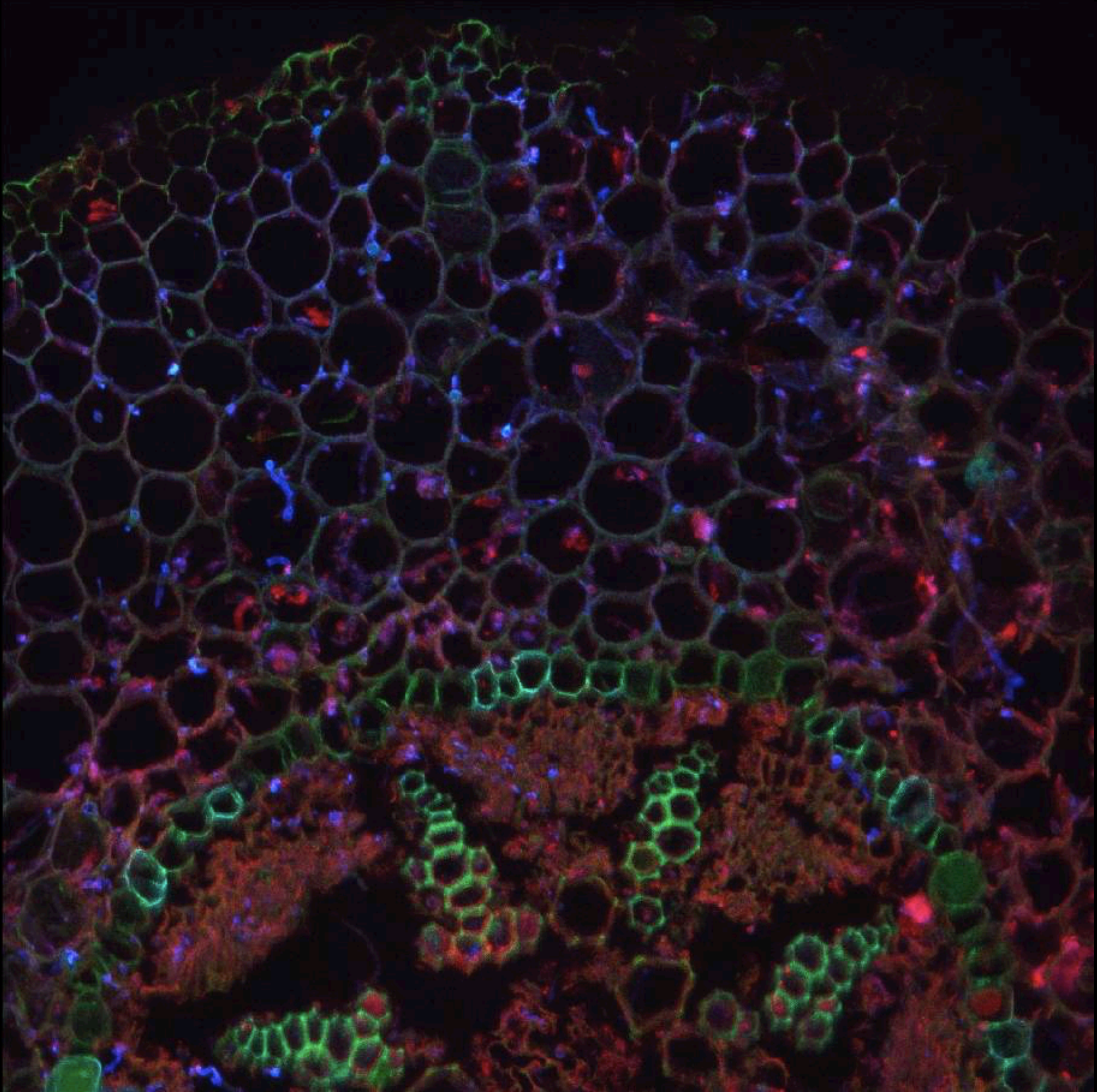

6 hpi

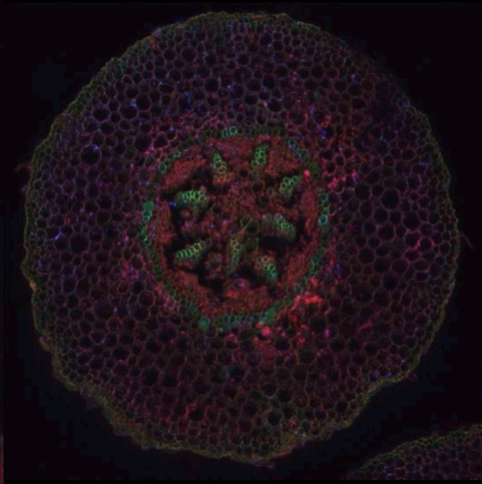

12 hpi



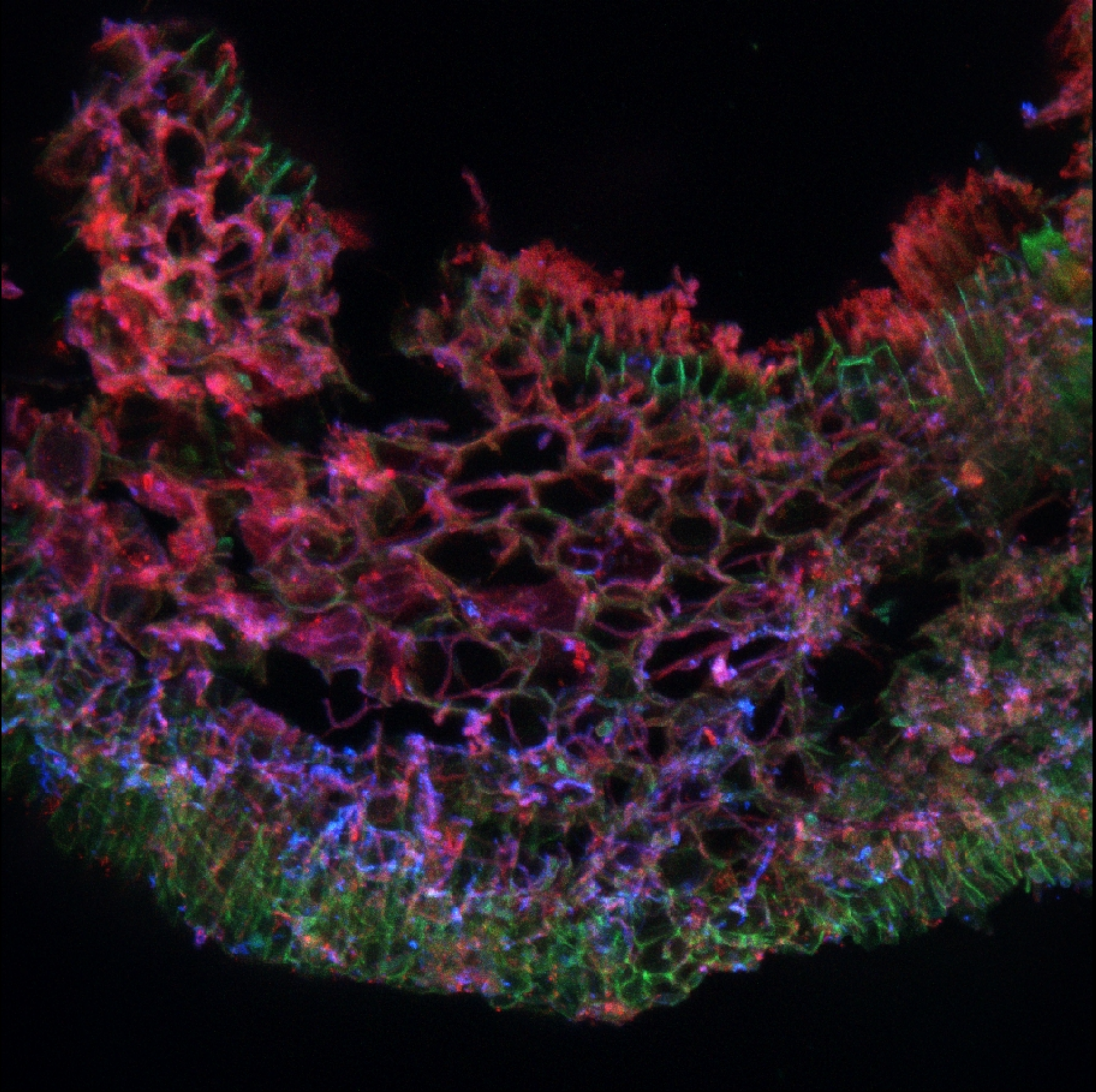


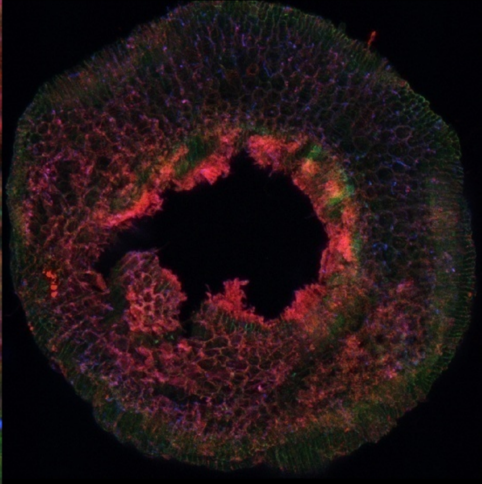
24 hpi





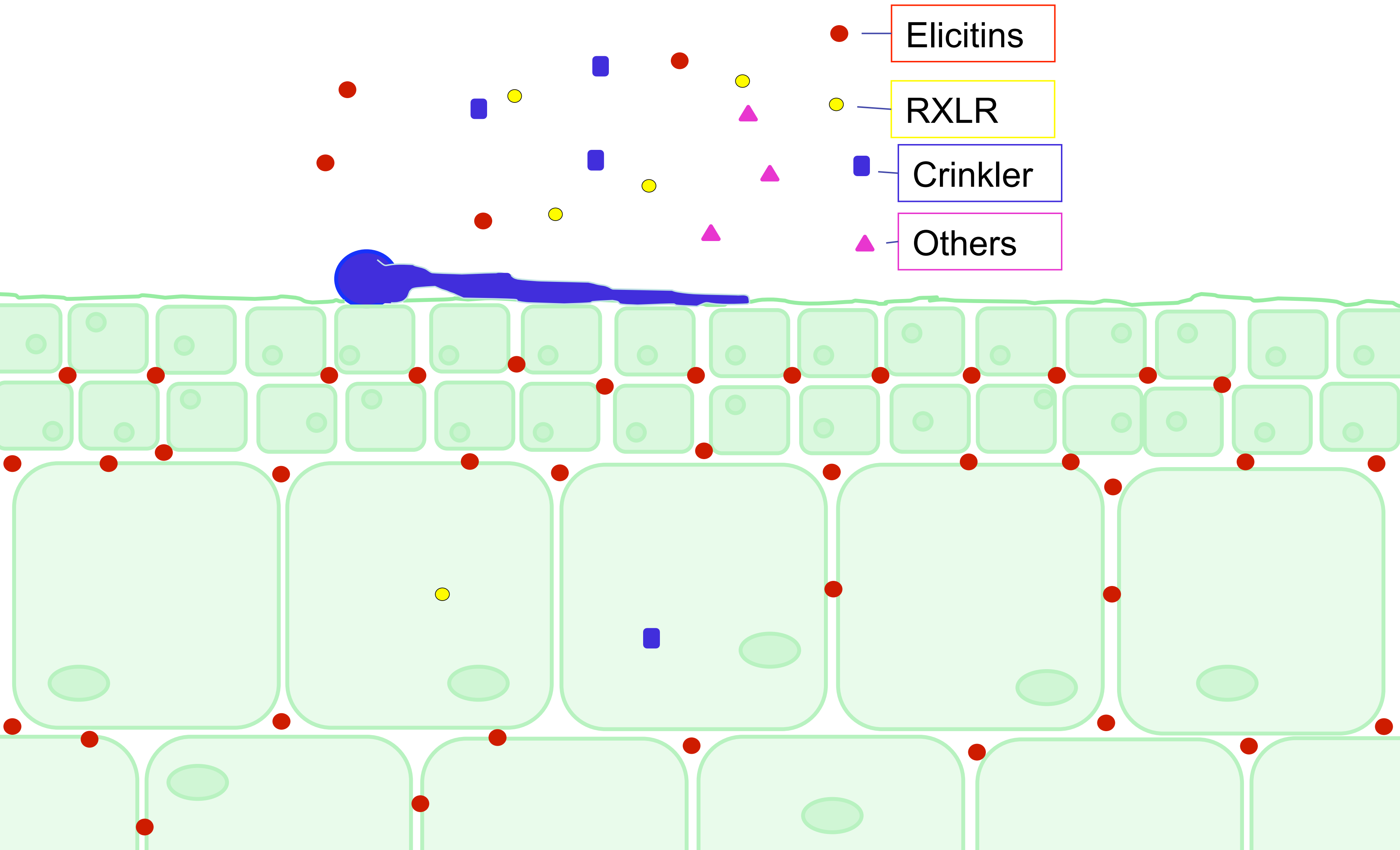
96 hpi

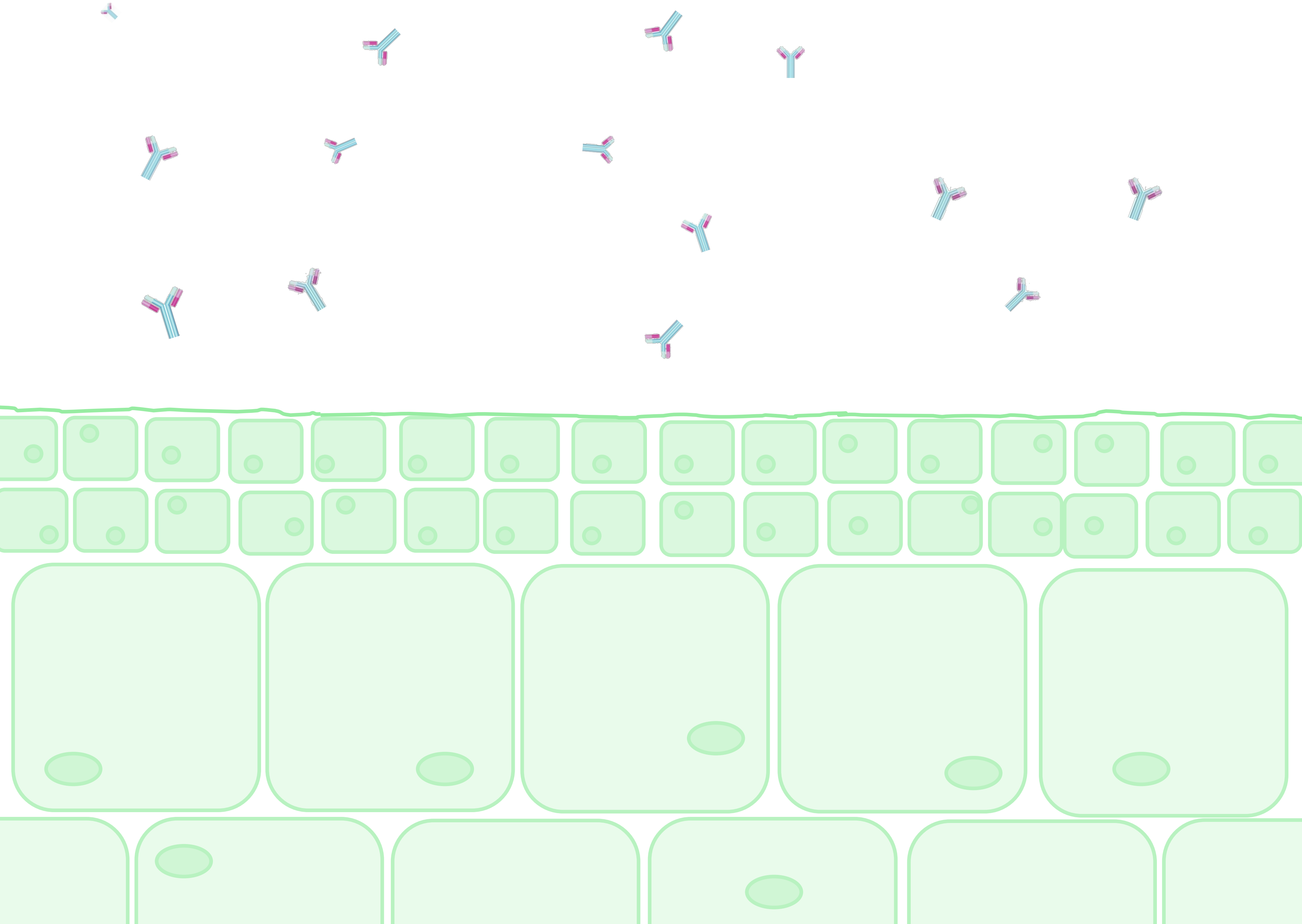


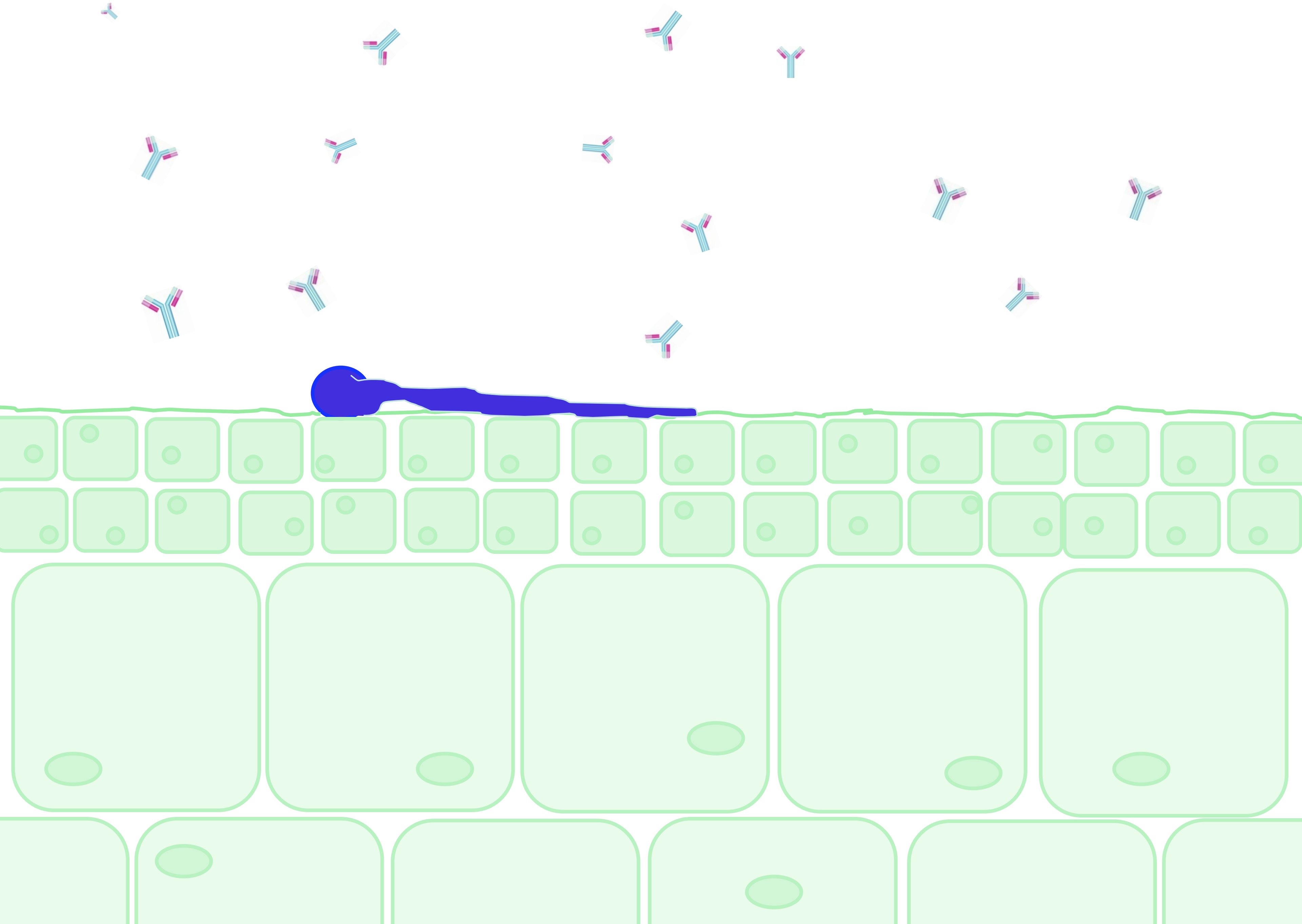


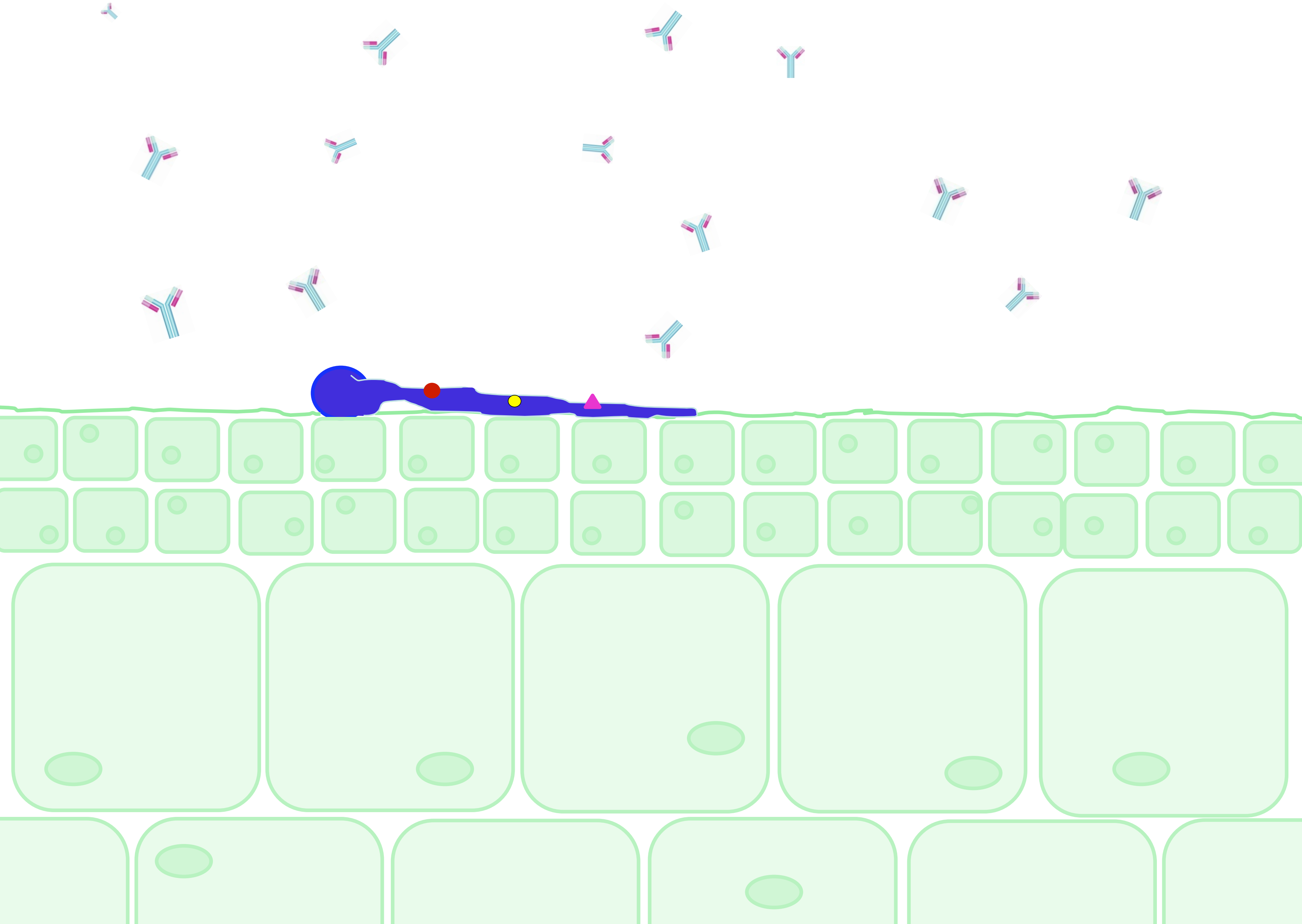
100 % Mortality

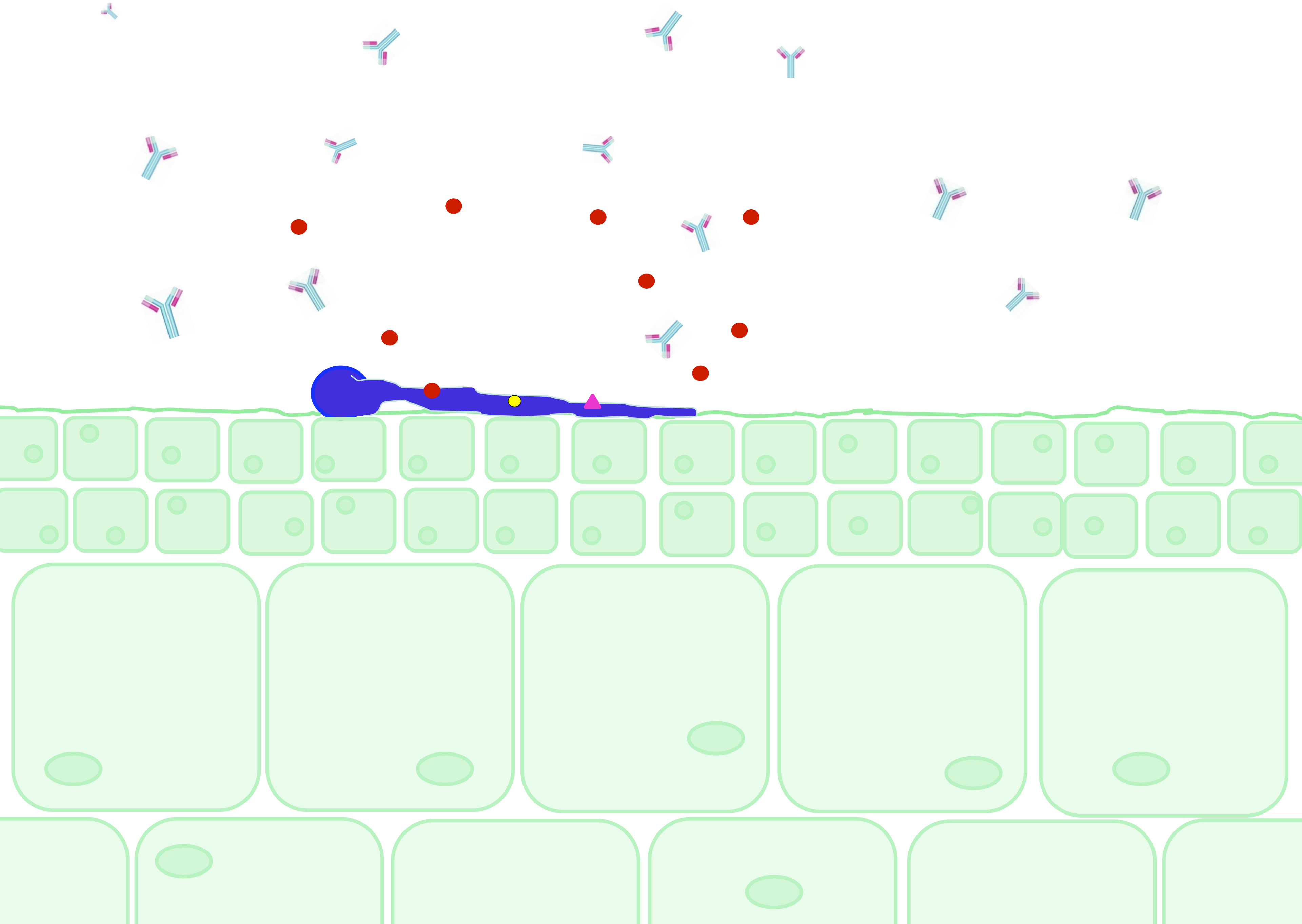
192 hpi

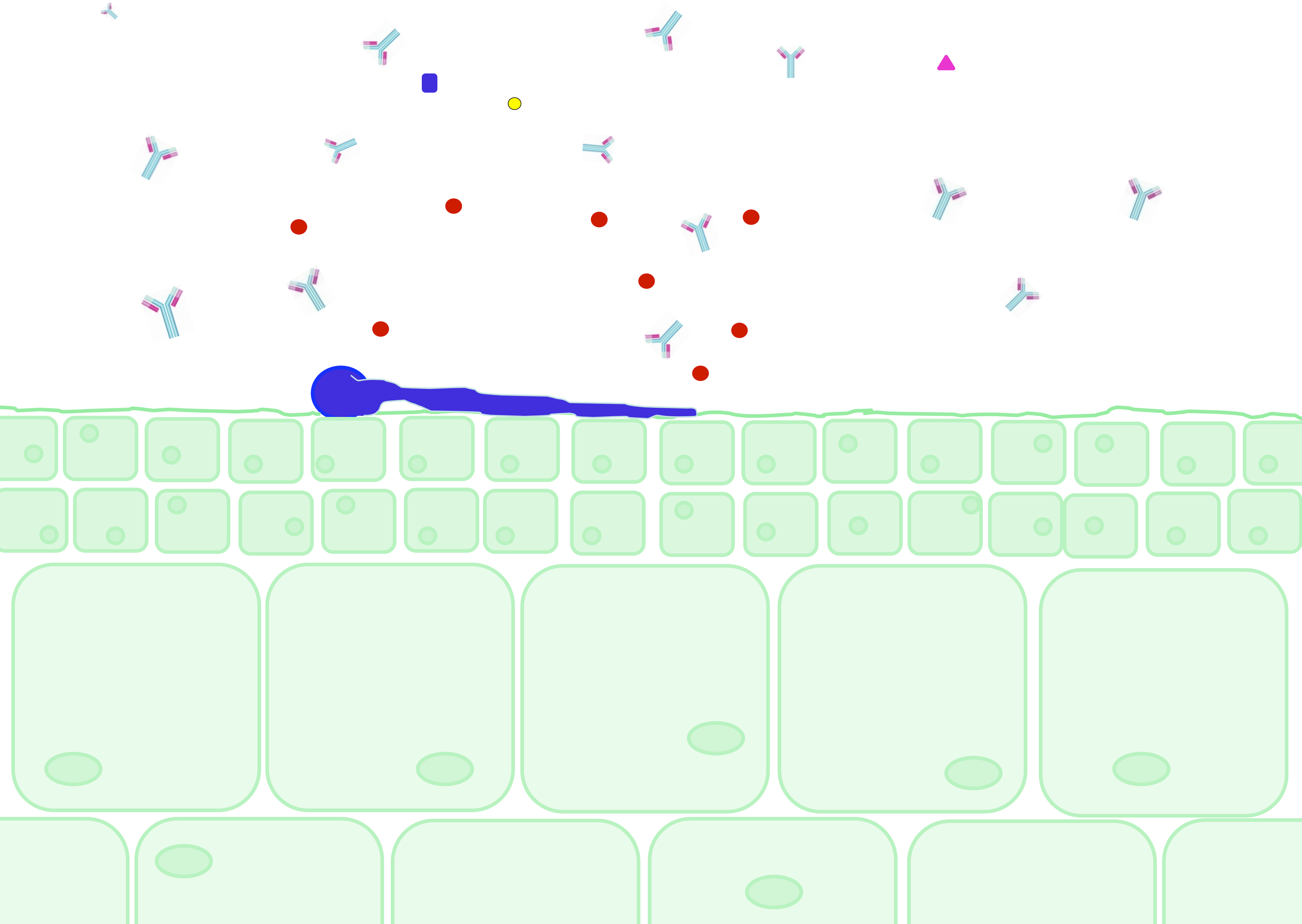

Elicitins
RXLR
Crinkler
Others

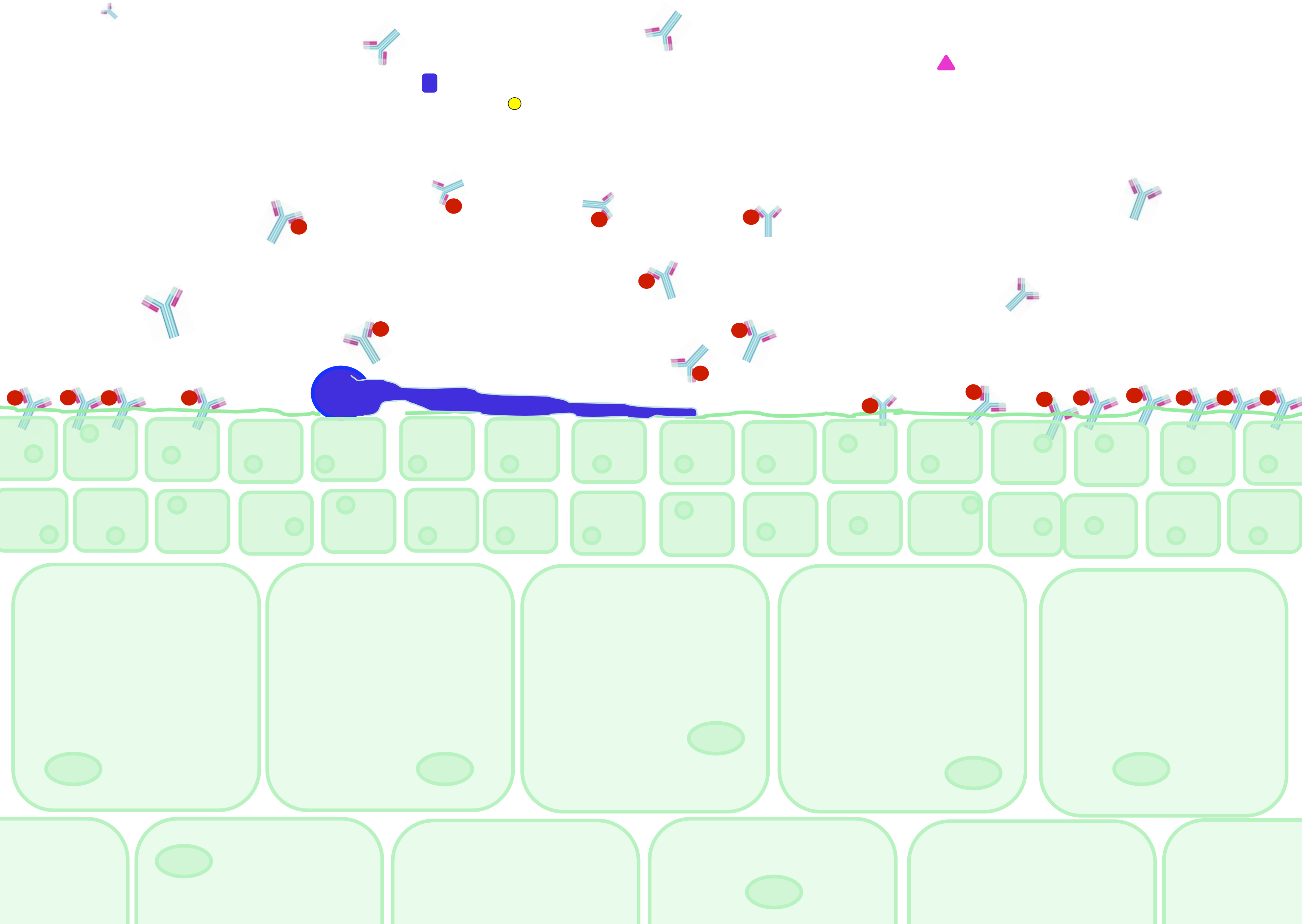




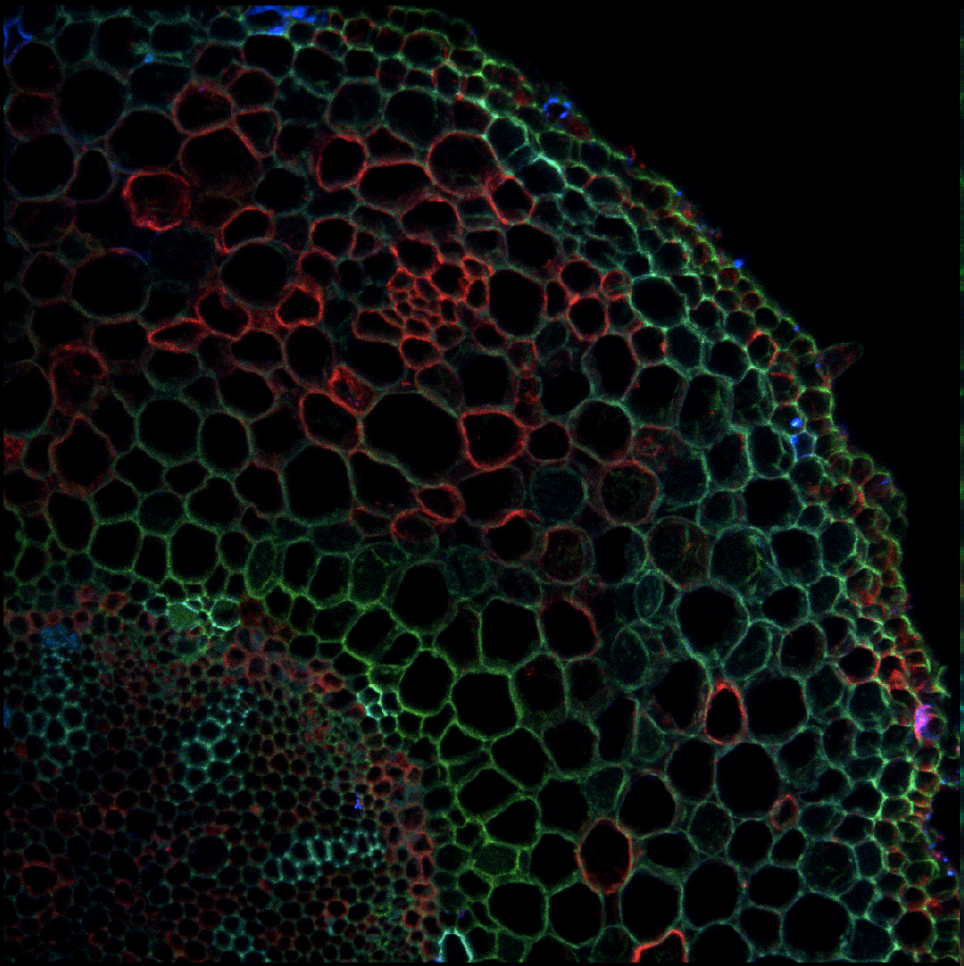




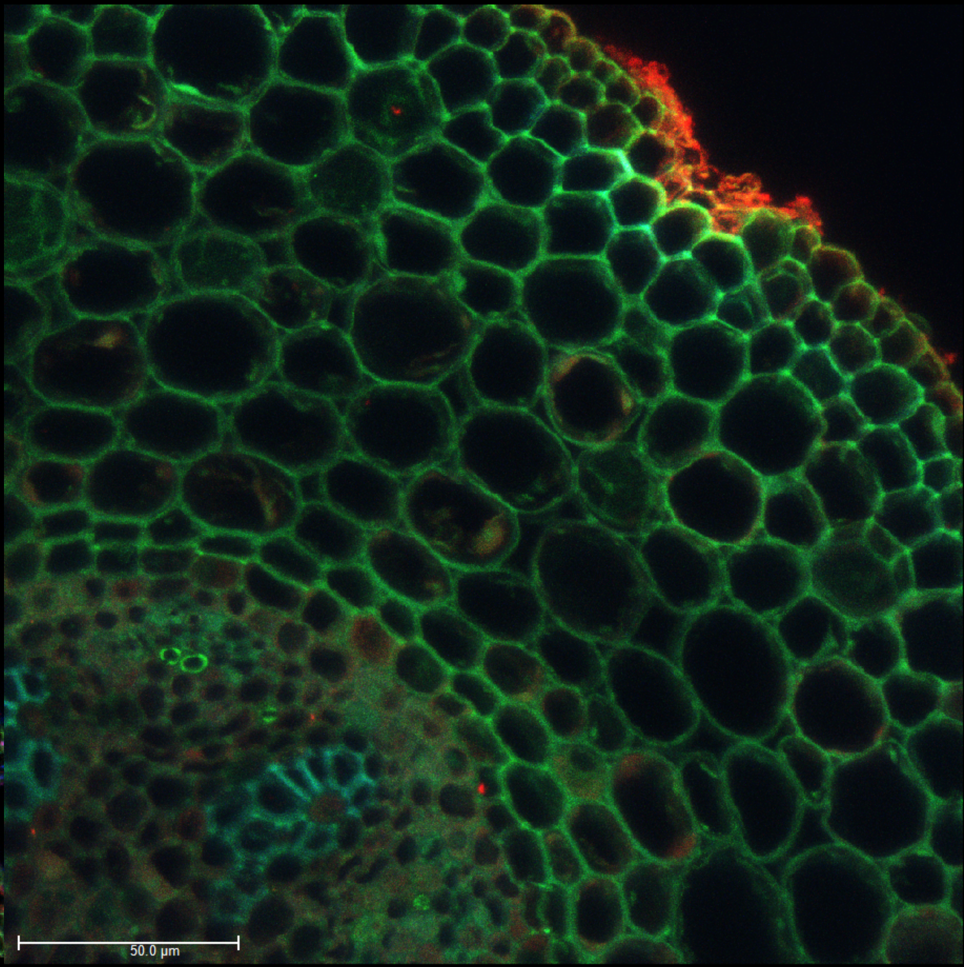




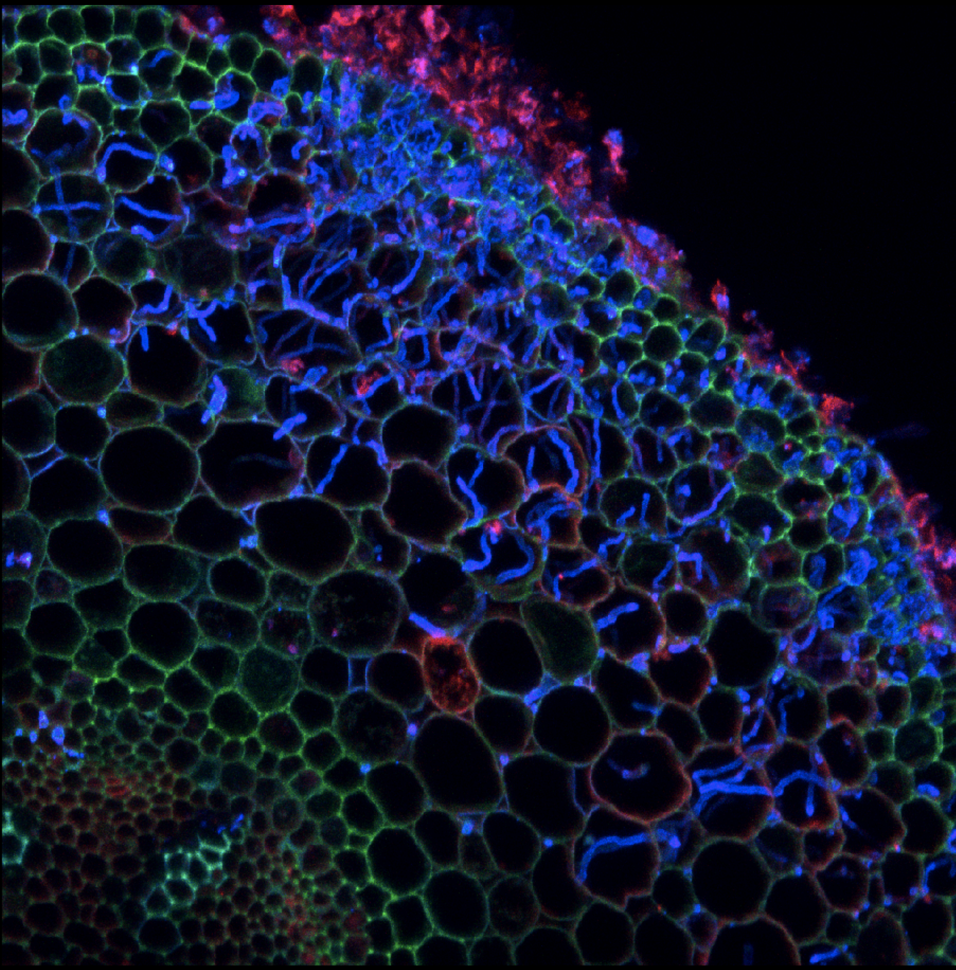
12h



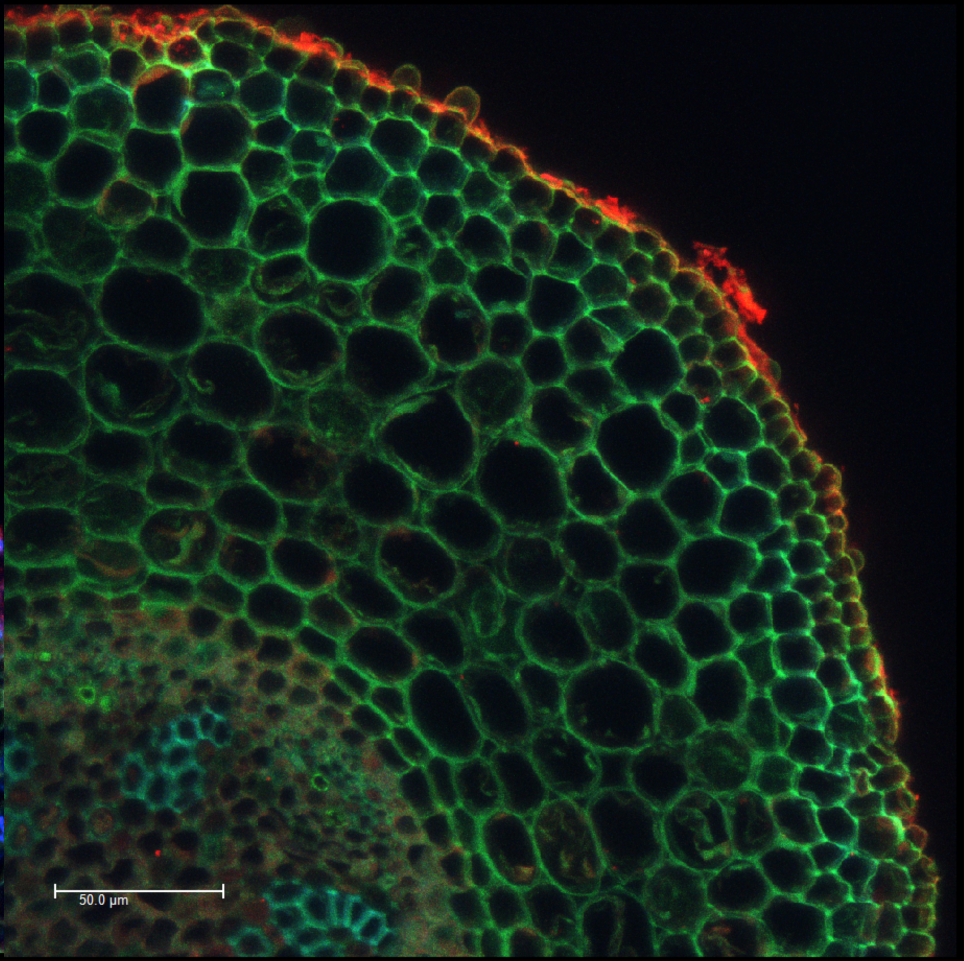
12h + Antibody



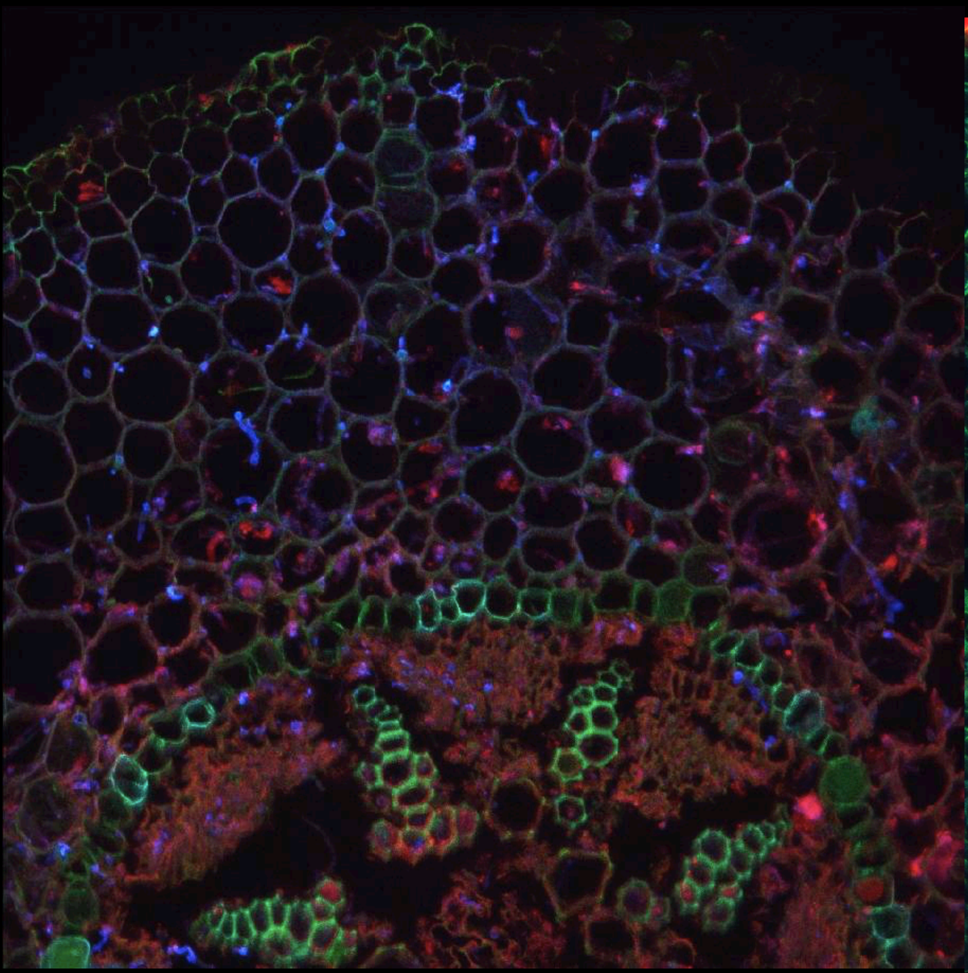
24h



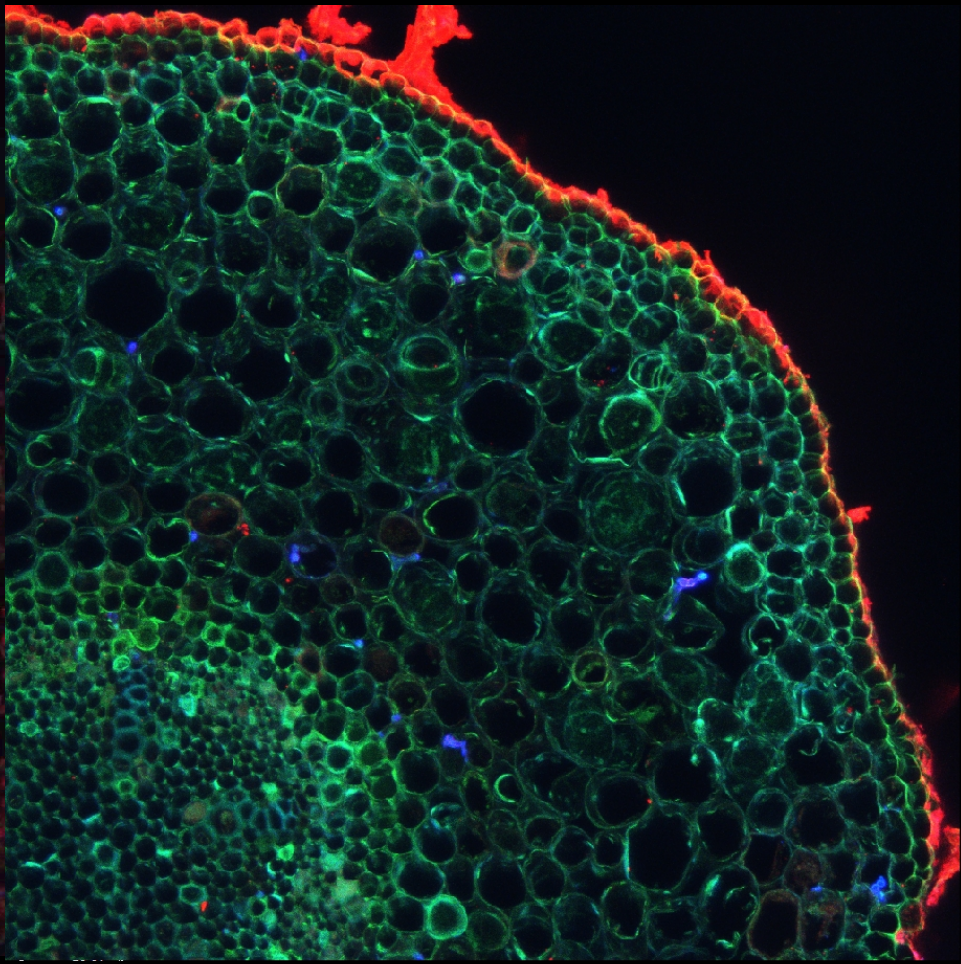
24h + Antibody



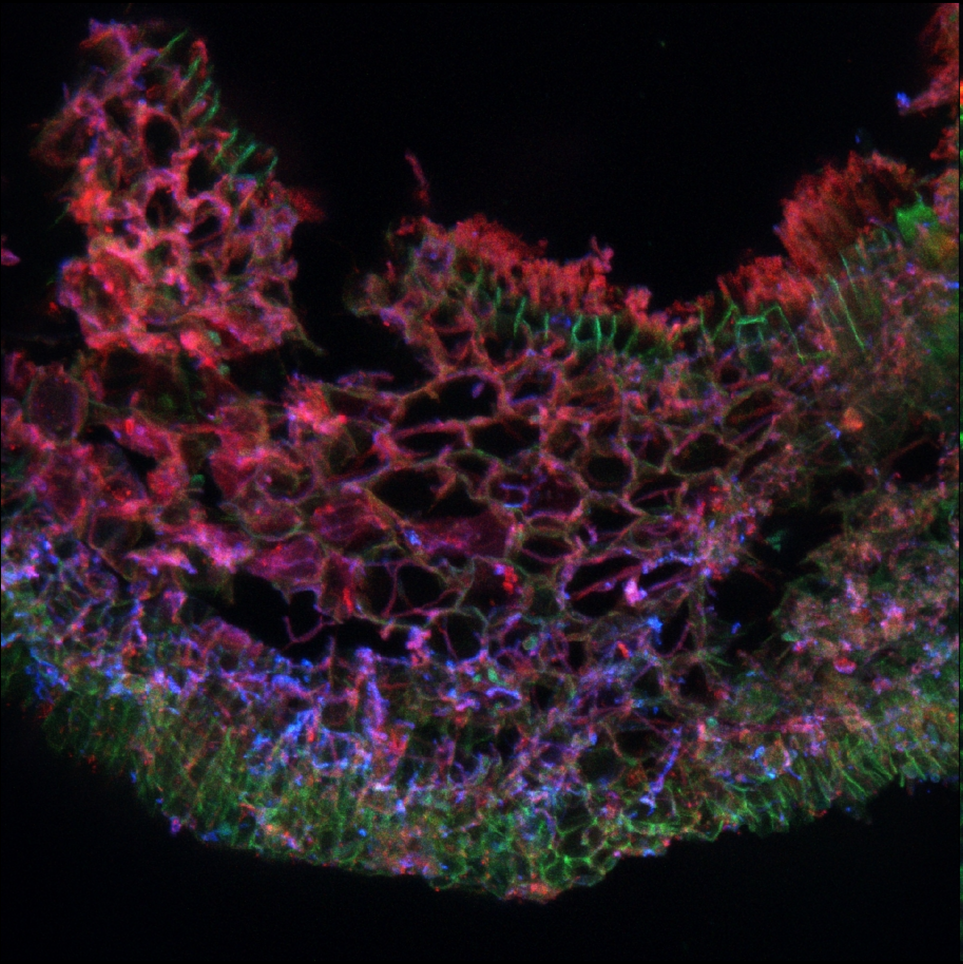
96h



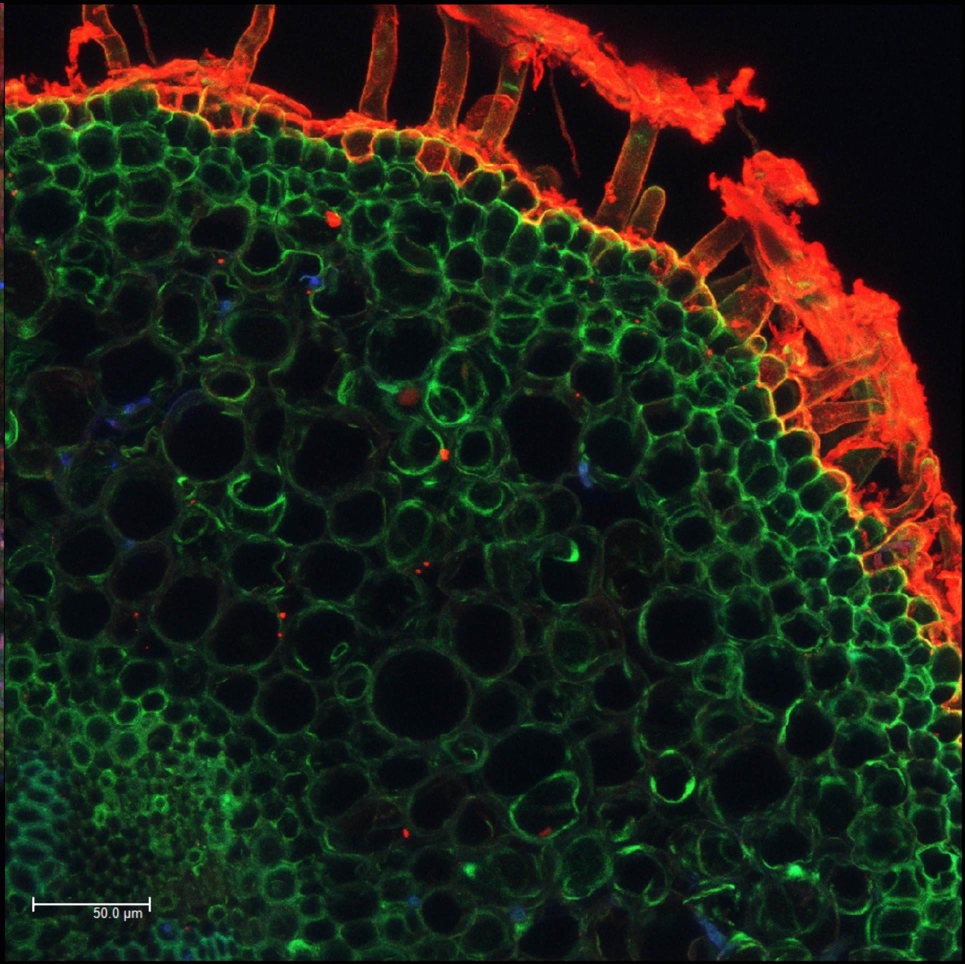
96h + Antibody

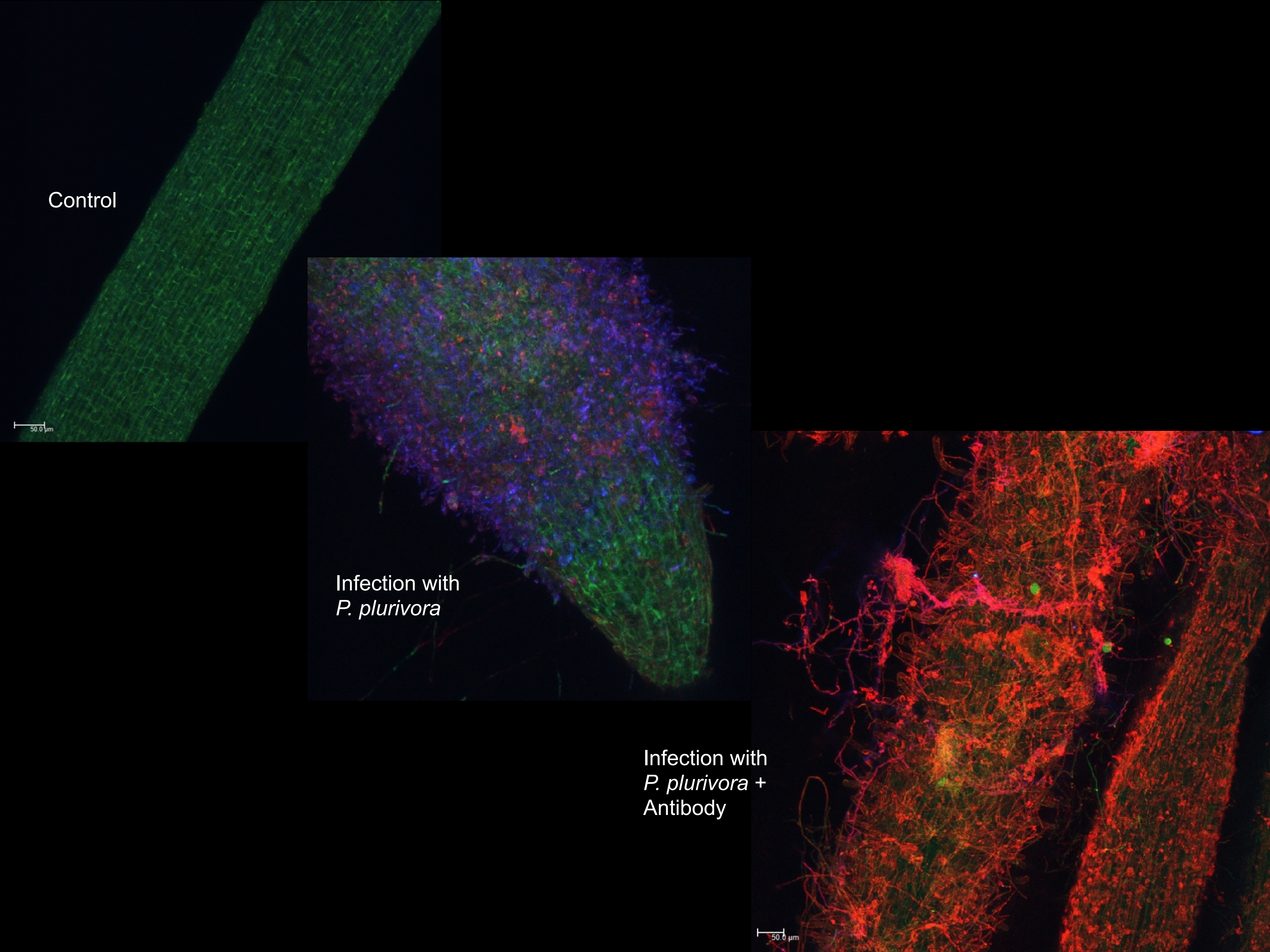


192h

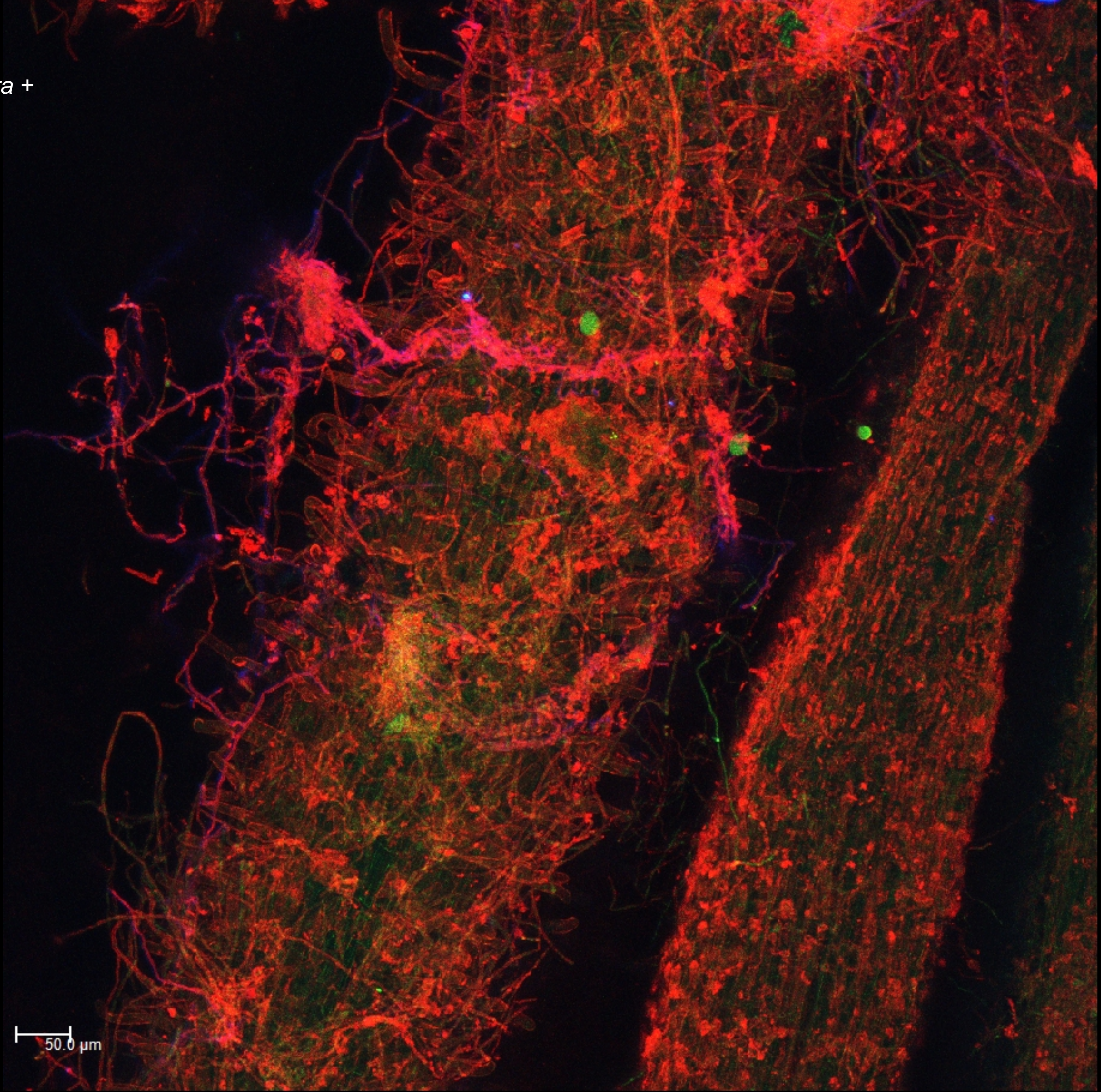


192h + Antibody




Control
Infection with *P. plurivora*
Infection with *P. plurivora* + Antibody

96 h *P. plurivora* +
antibody



Absence of α-plurivorin – resistant interaction

Presence of α-plurivorin – susceptible interaction

Co-evolution
(Arms- race)