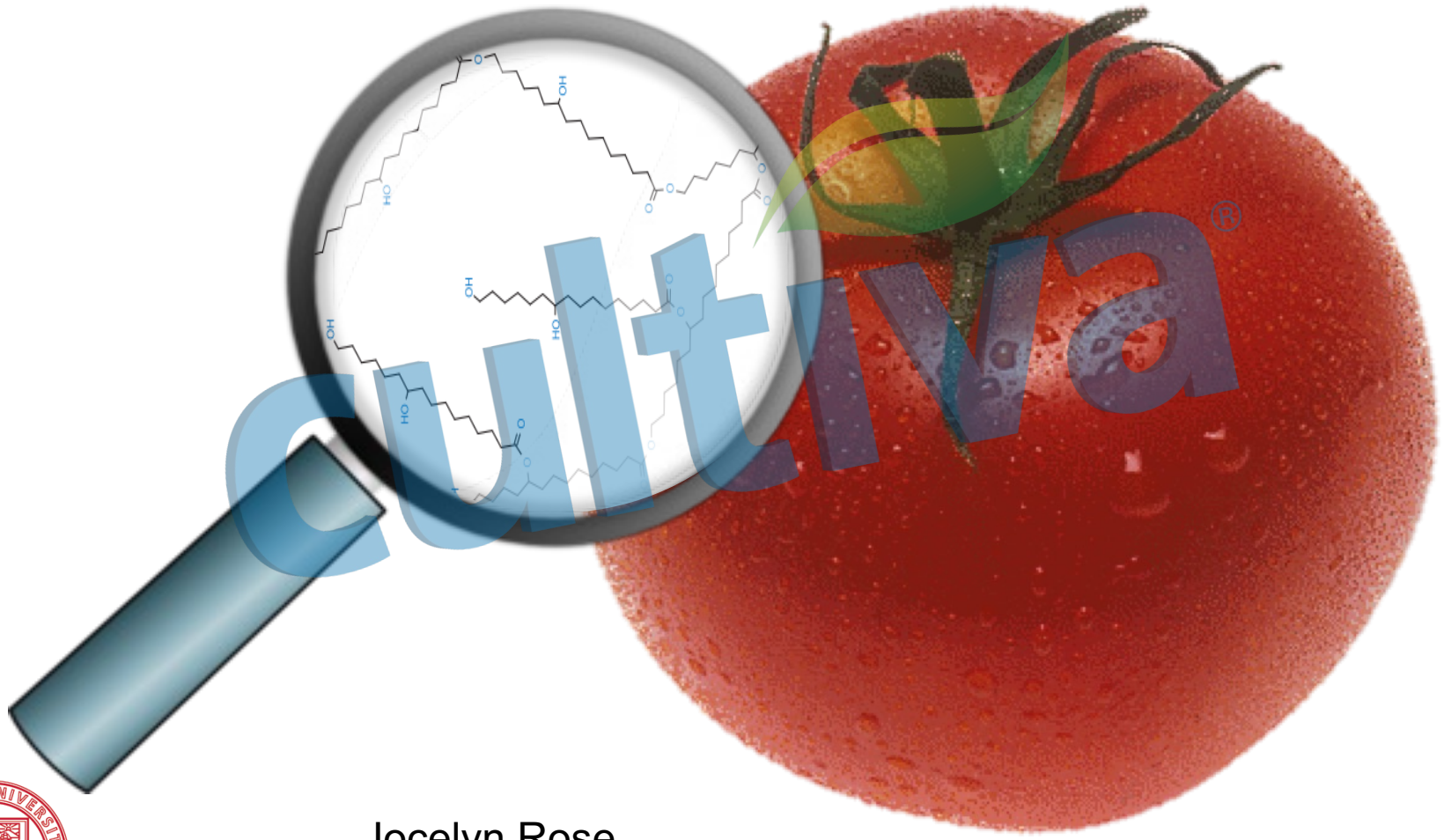
“Cuticle 101”



Jocelyn Rose
School of Integrative Plant Science
jr286@cornell.edu

Cornell University

There will be no test!!!

“I study cuticles…”

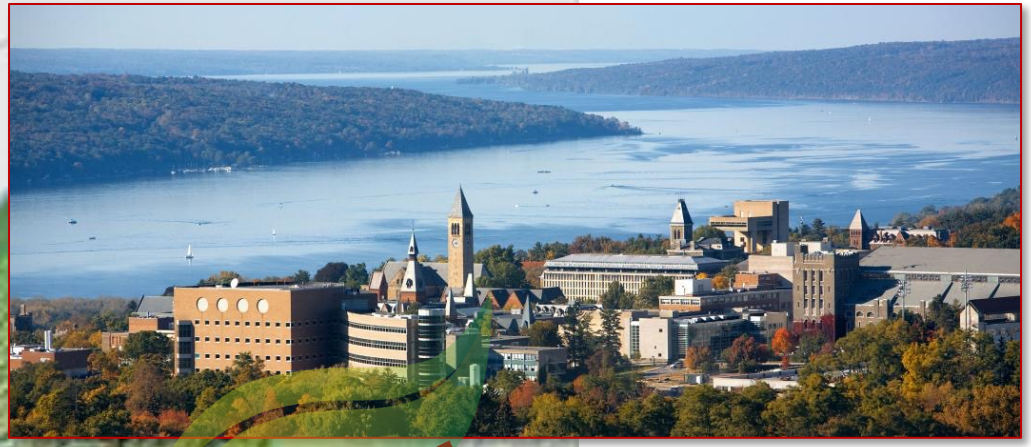
What non-scientists think I do

What Google thinks I do

What I think I do

Plant Cuticles: Specialized water-resistant cell wall structures that cover the surface of all ‘above-ground’ plant organs…plant “skins”

Geneva
"AgriTech"

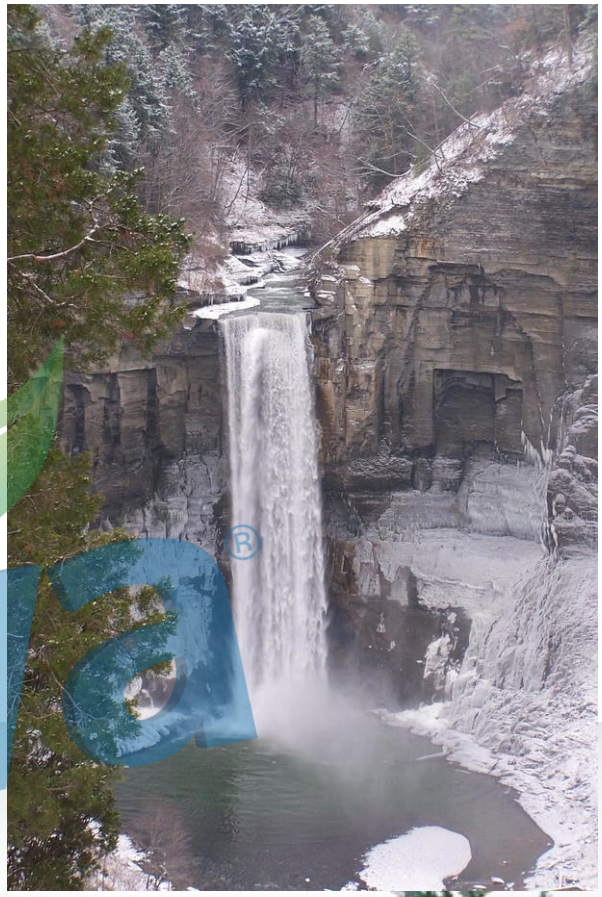


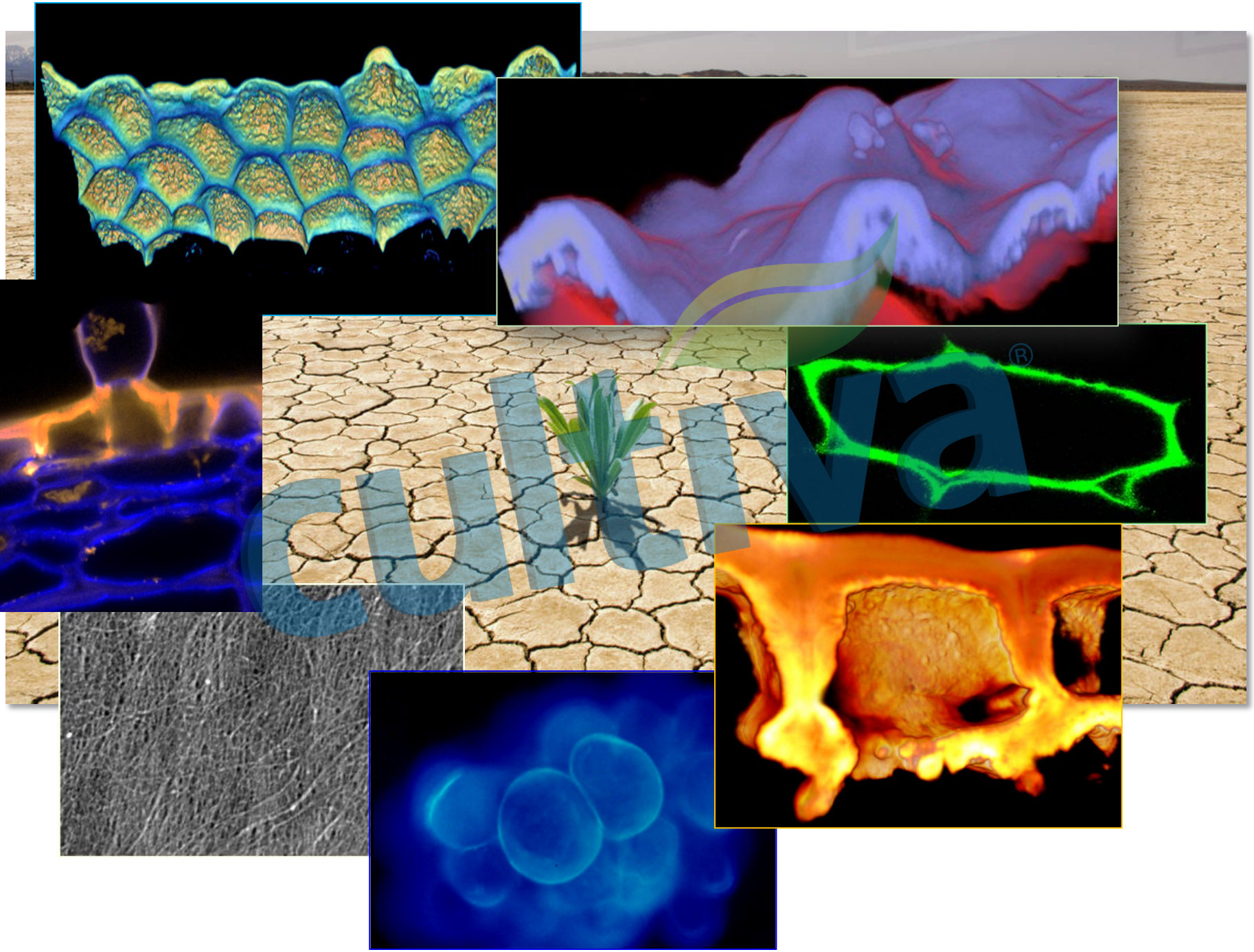
Ithaca

Long Island
Horticultural
Research and
Experiment Station
(LIHREC)

Cornell
University

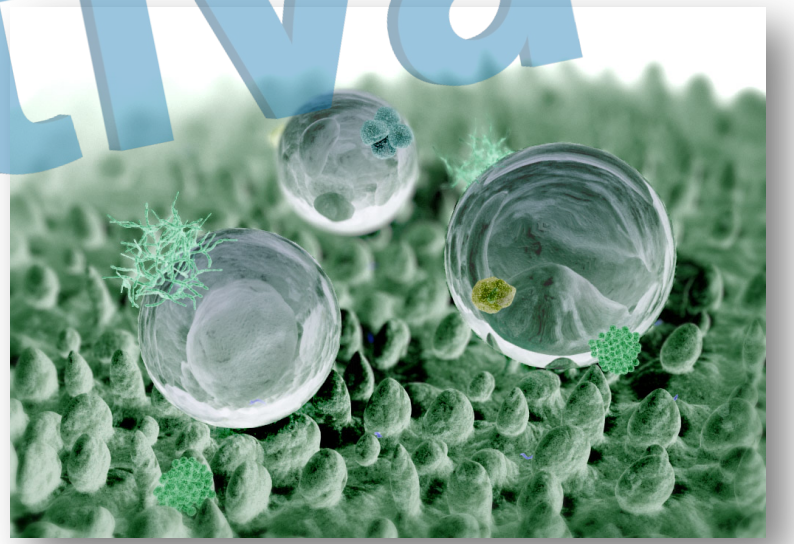
New York City





The Critical Importance of Plant Surfaces

Critical barrier function:
Water loss/uptake
Resistance to disease
Environmental protection
Self-cleaning

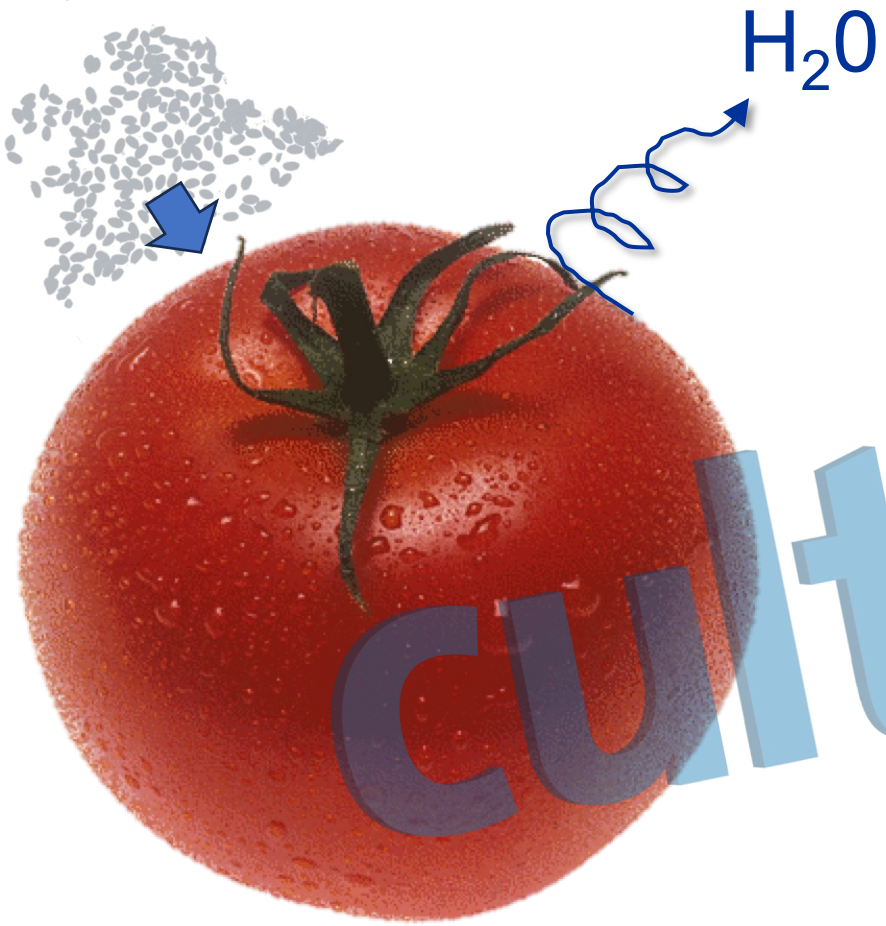


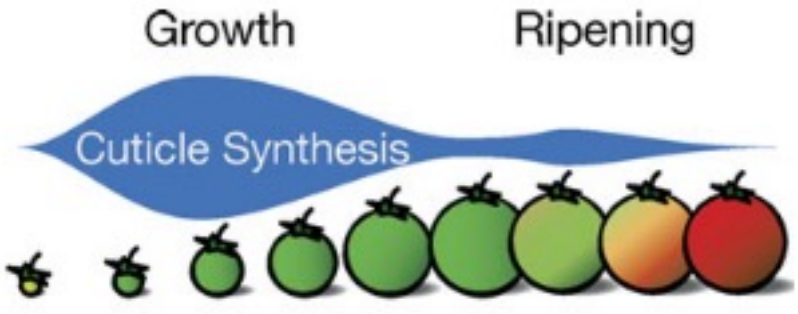
"Whole Plant" Cuticle Biology

Tomato fruit: a model for cuticle research

- Biochemical compositon
- Linkages between components
- Assembly and architecture
- Restructuring

Fungi/bacteria





Engineering challenges

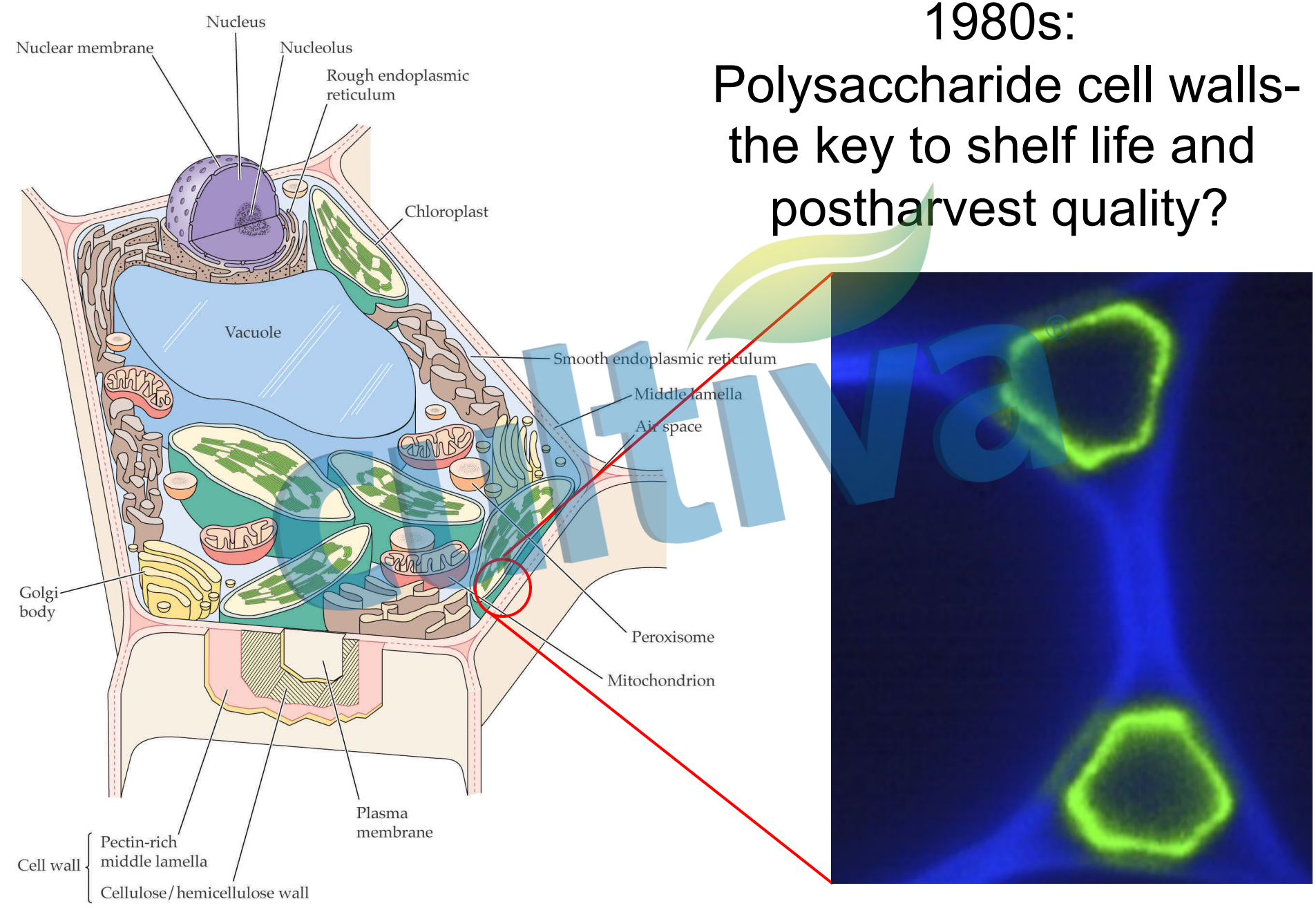
- Biomechanically strong
- Chemically resilient and impermeable
- Elastic and plastic properties
- Dynamic and self-repairing

How do plants make, modify and maintain their protective “skins” (cuticles)?

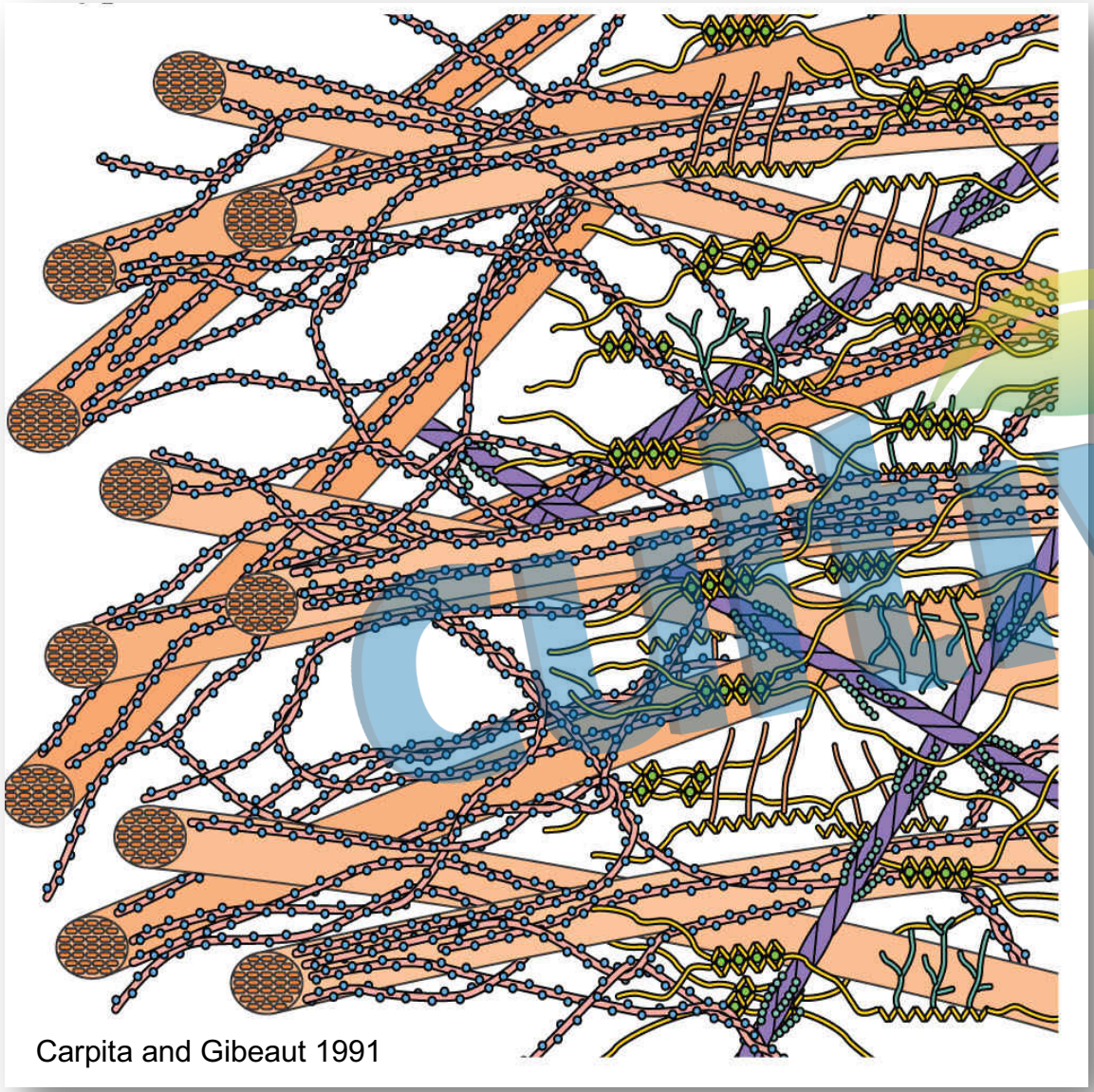
Desirable Ripening-Related Traits

Color	Flavor	Aroma	Texture
-Carotenoids -Flavonoids -Anthocyanins	- Sugars - Organic acids	-Diverse volatiles	???

1980s: Polysaccharide cell walls- the key to shelf life and postharvest quality?



The plant cell wall …a complex polymeric network



Carpita and Gibeaut 1991

Cellulose
Hemicelluloses
Pectins

PG

The Mystery of Fruit Degradation….

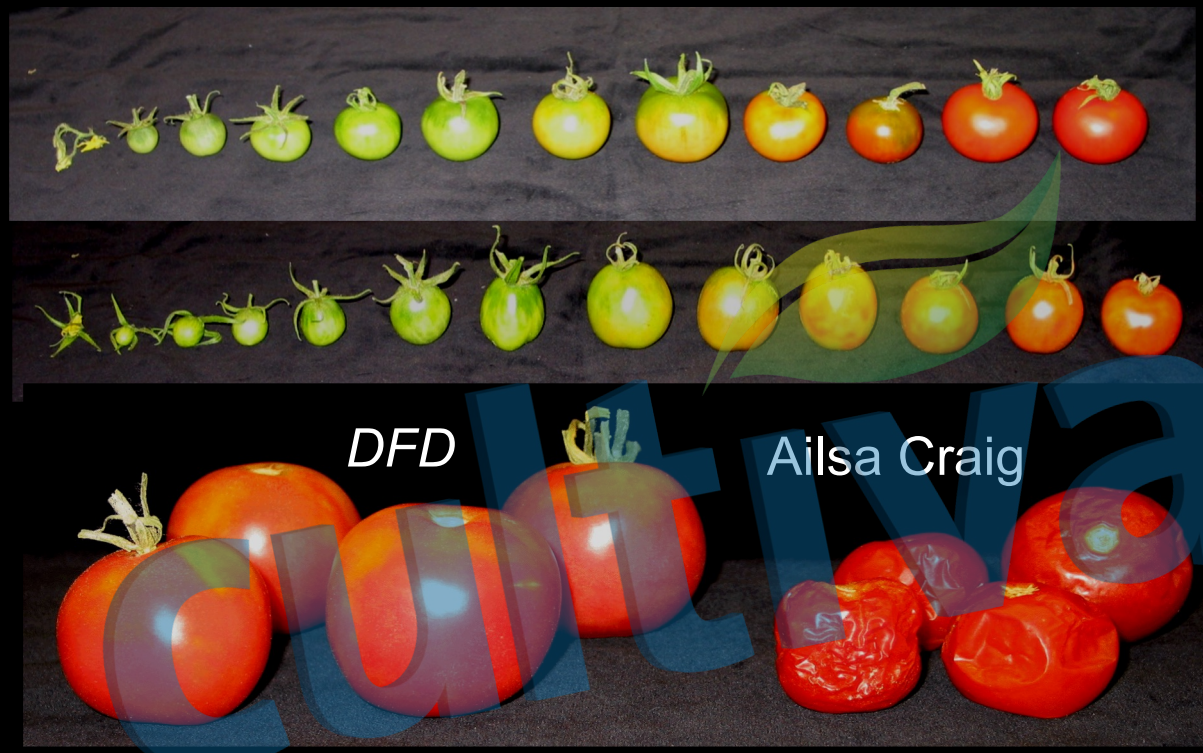
FlavrSavr ™

- Cell wall degradation

- Reduction in cell-to-cell adhesion

$$$$- why can't we prevent this?

A game changer: Delayed Fruit Deterioration (*DFD*) mutant



Ailsa Craig cultivar

DFD

3 months 6 months 9 months

Four Month Time Lapse Study of *DFD* and Ailsa Craig Ripening

Montse Saladie
Jocelyn Rose

2001

Postharvest Disease Resistance

It's all in the 'skin'?

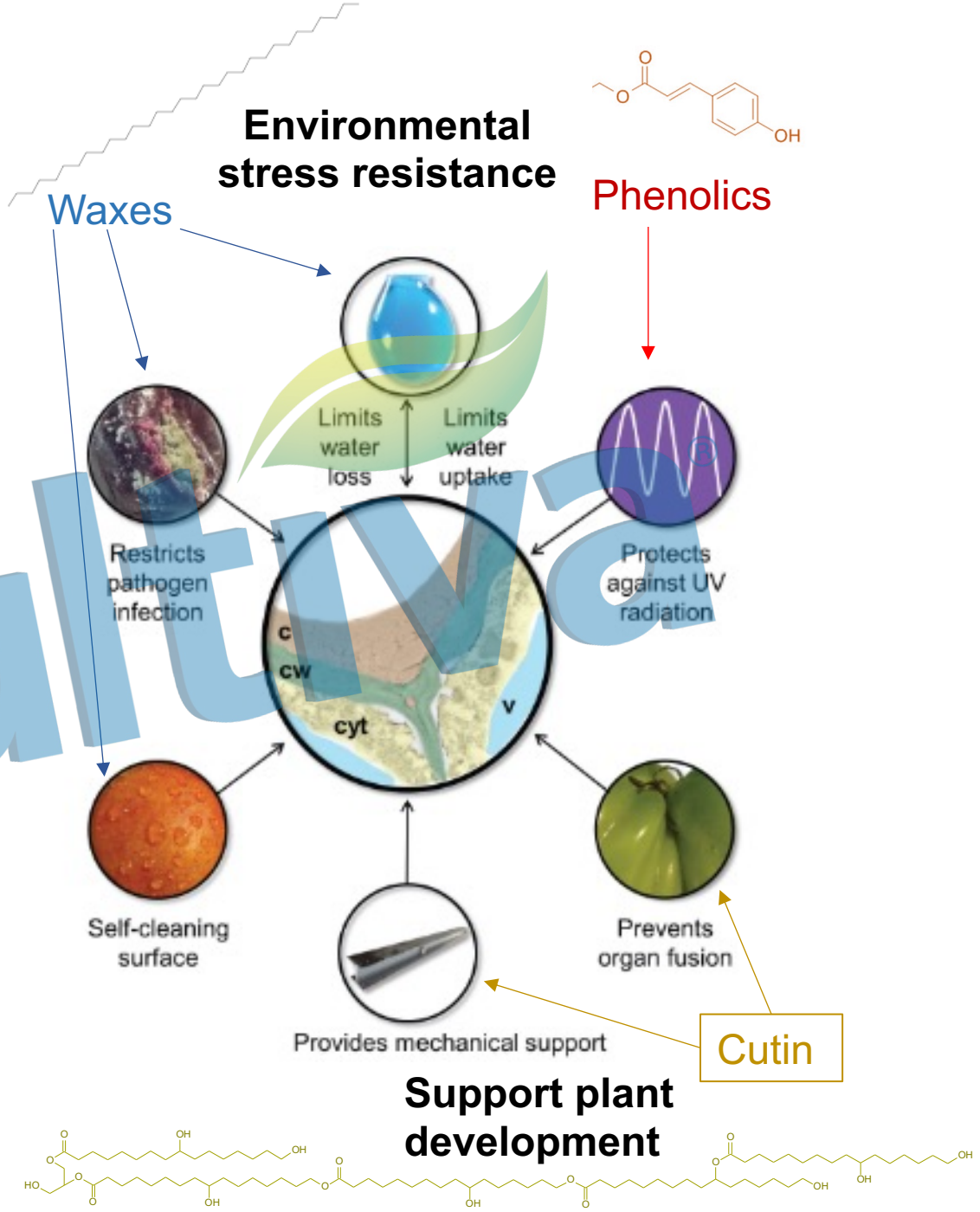
Fungal inoculation

Punctured

Commercial Cultivar | Ailsa Craig | *DFD*

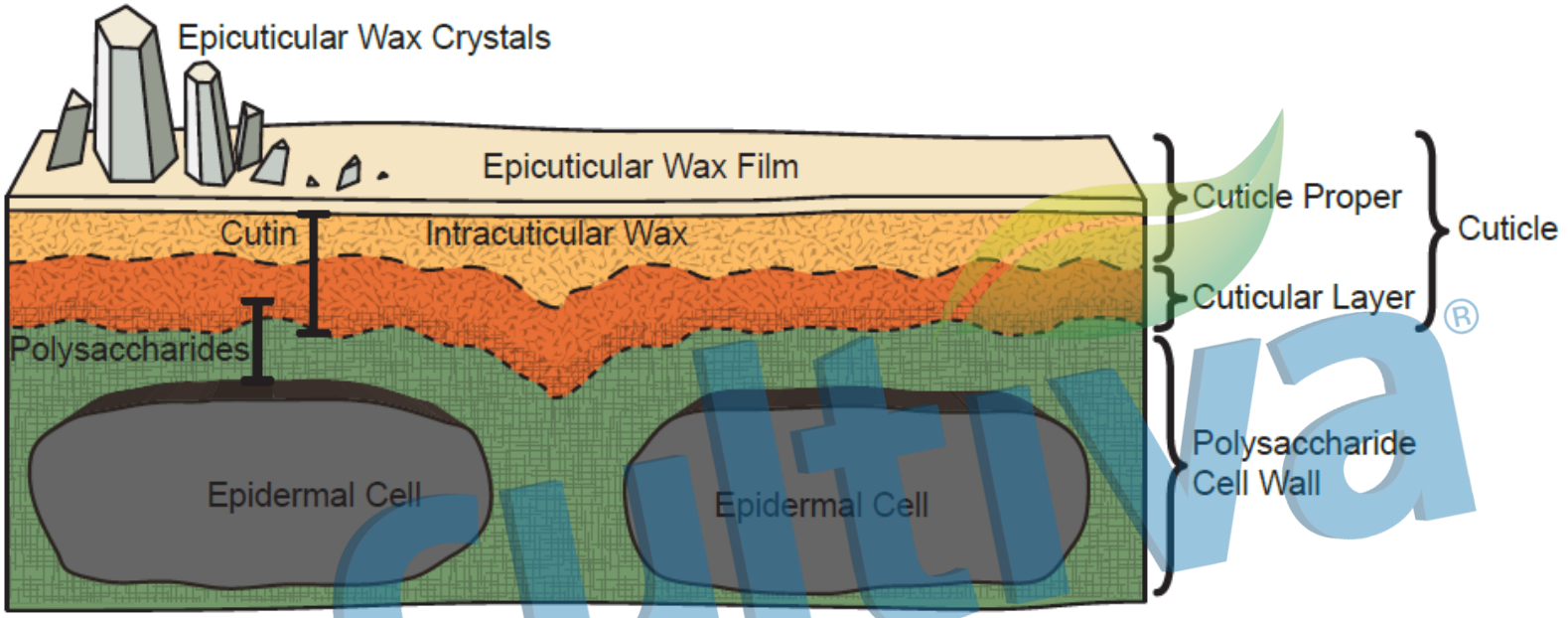
Surface

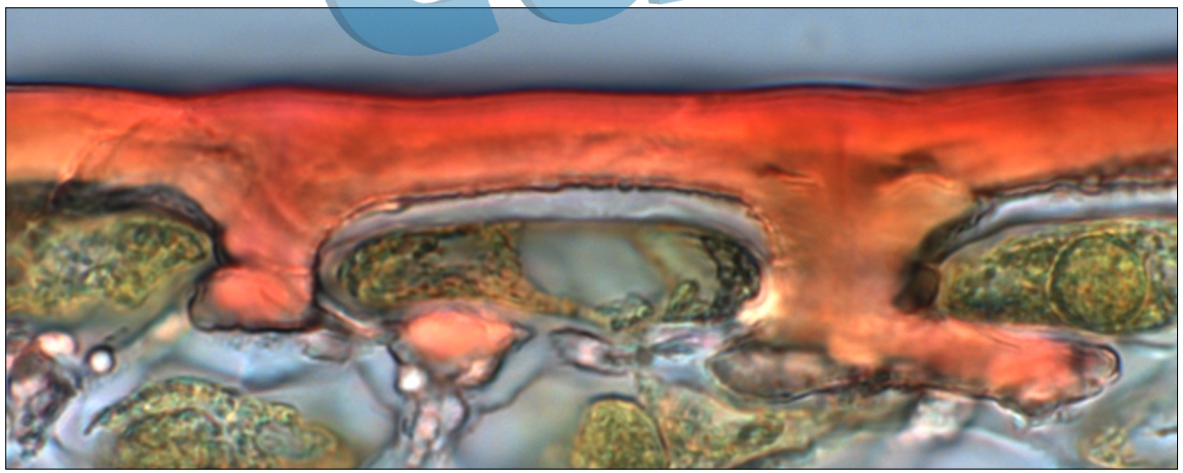
The plant cuticle: a multifunctional structure



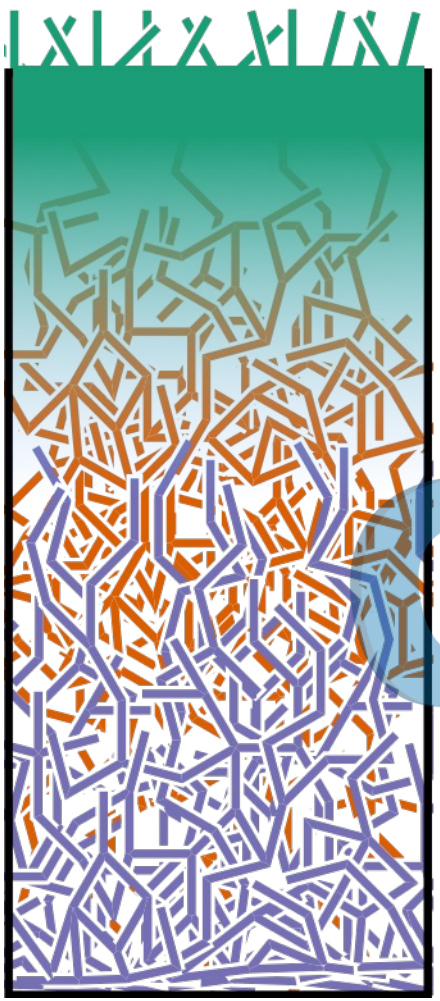

Cuticle
Polysaccharide cell wall
ON
OFF
ON
OFF

The Plant Cuticle:
a specialized hydrophobic cell wall





Bridging structure and function



Cuticular waxes [SEALANT]

Cutin [SCAFFOLD]

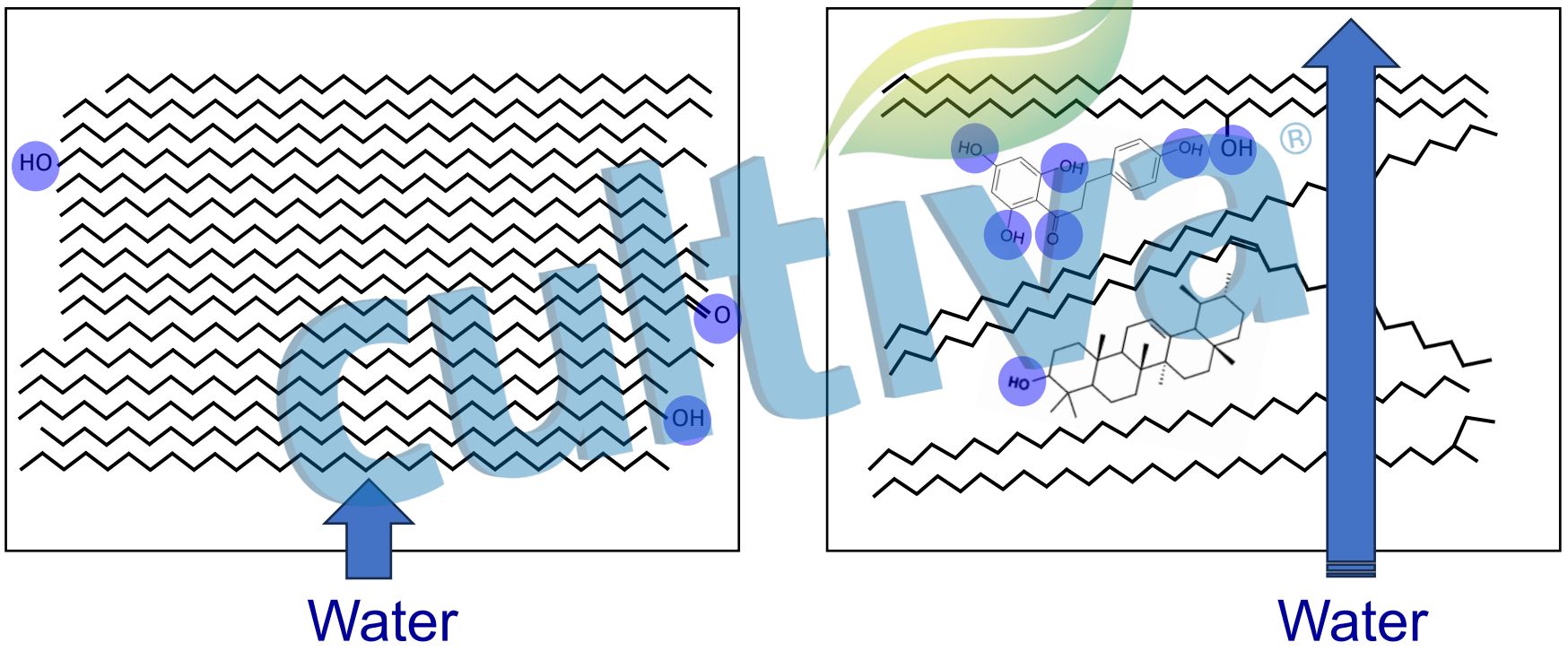
Cell wall polysaccharides

Questions, questions, questions…..

- How do different wax components affect permeability?

Crystalline (impermeable)

Amorphous (permeable)

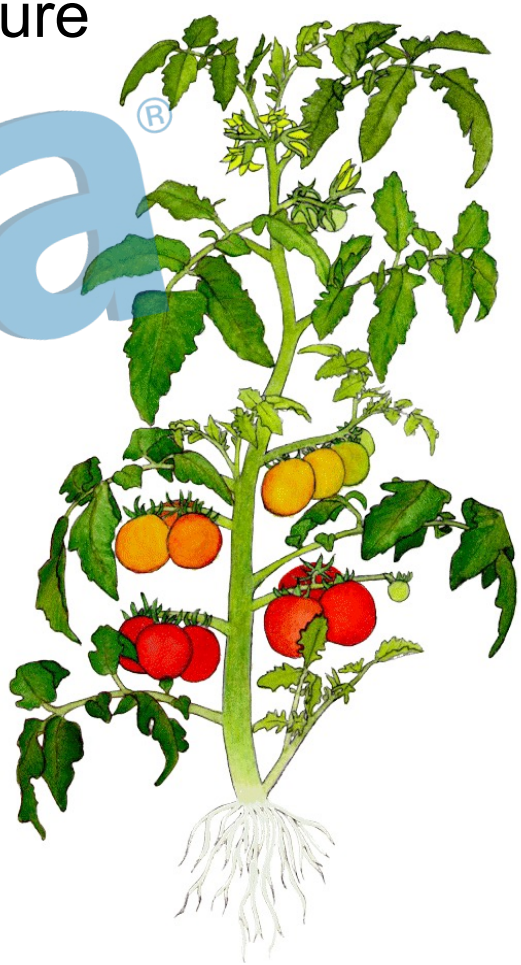


- How is cutin made and deposited into complex structures?

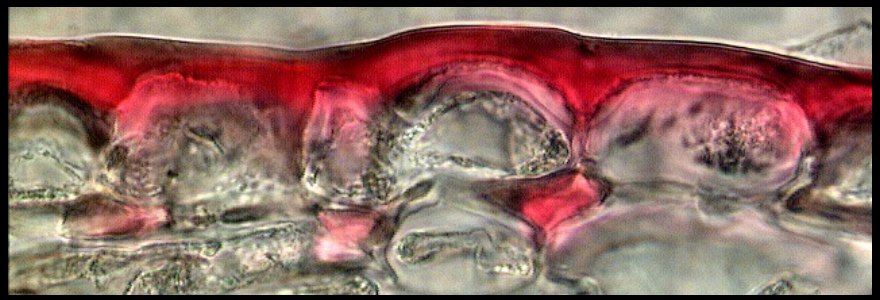
- How is the cuticle attached to the polysaccharide cell wall?

New Technologies to Understand Cuticle Structure Dynamics and Function

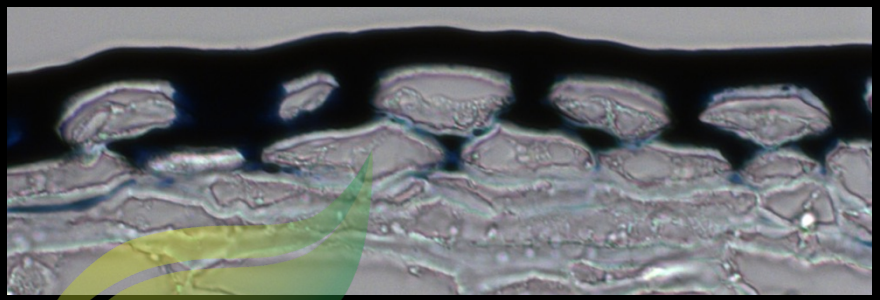
- High resolution imaging of cuticle architecture
- Cell type specific genes
- Cuticle proteins
- Forward and reverse genetics



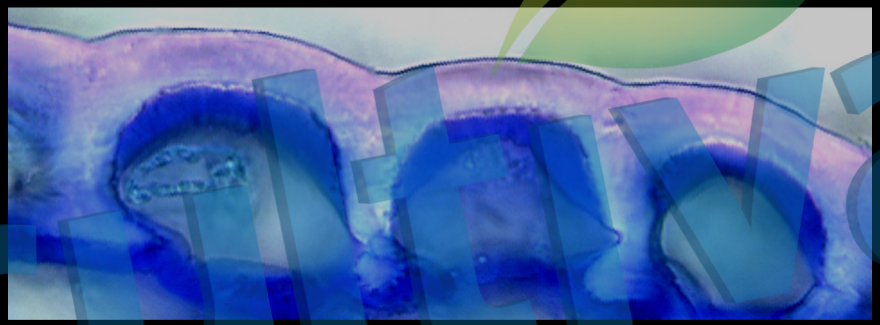
Histochemical stains for cuticle imaging



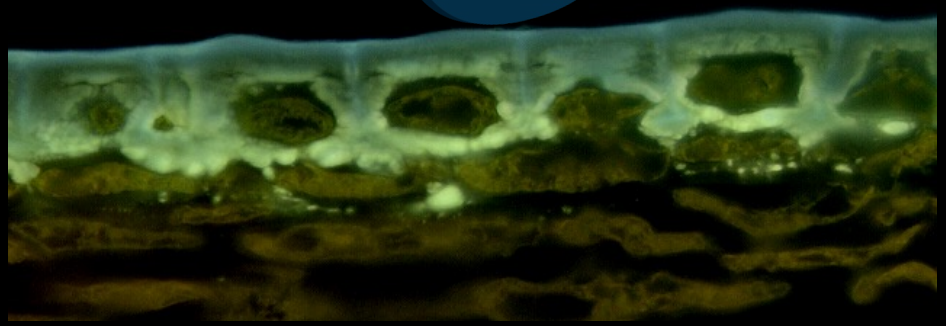
Sudan IV



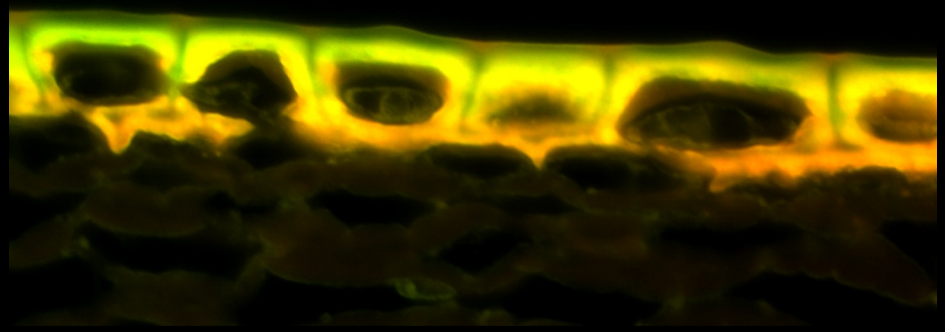
Sudan Black B



Nile Blue A

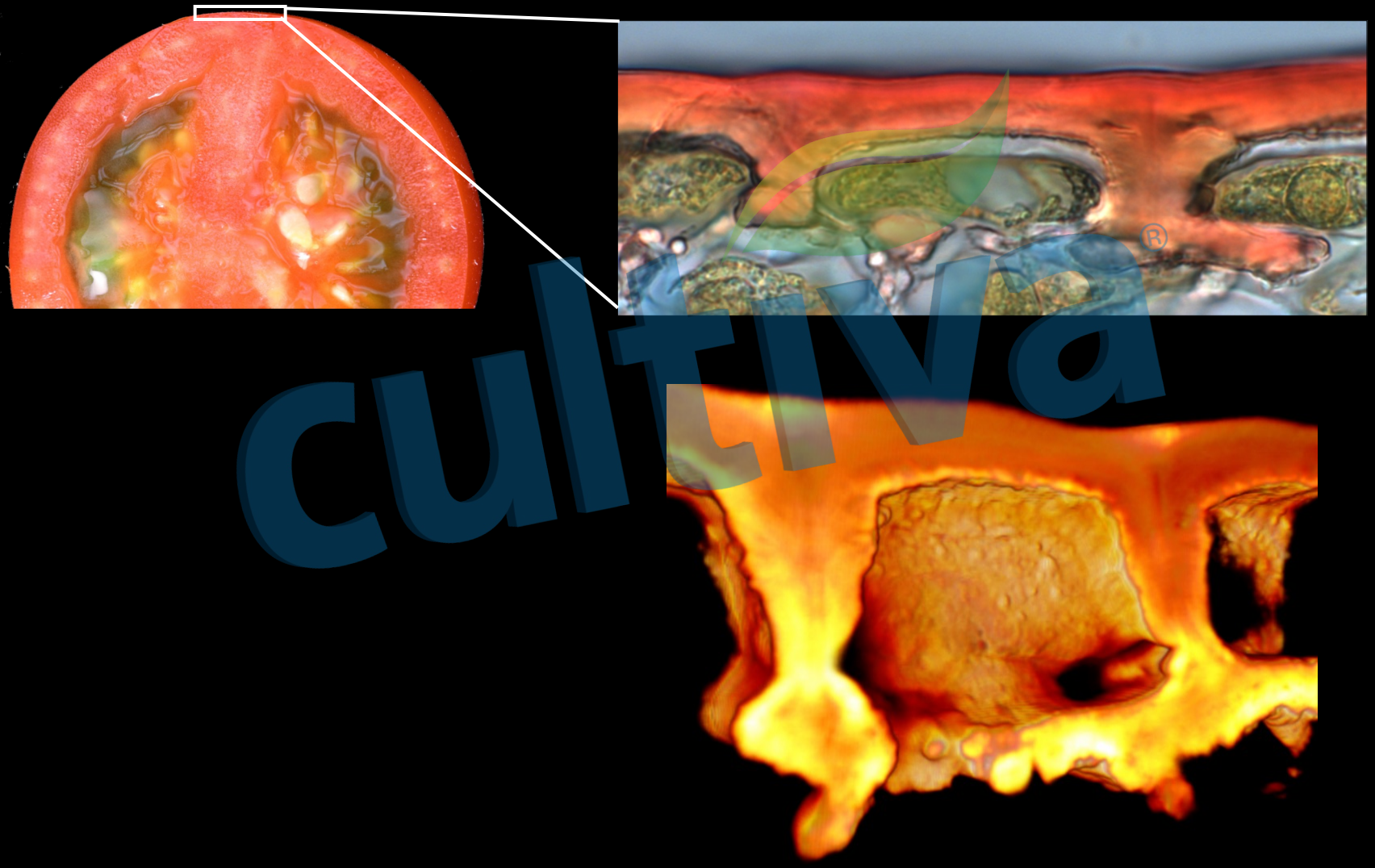


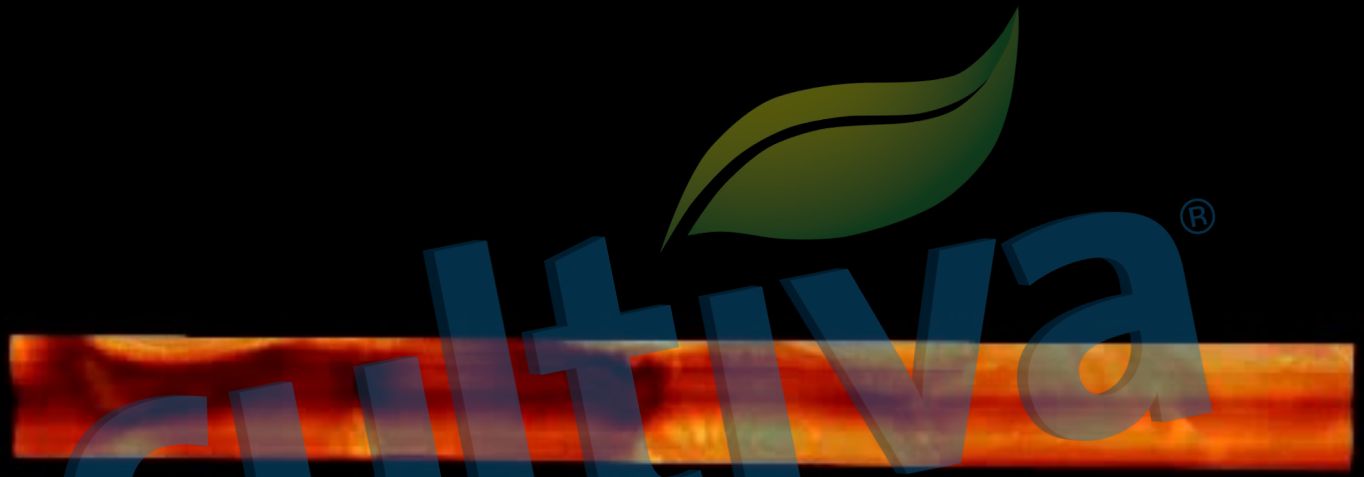
Auramine O

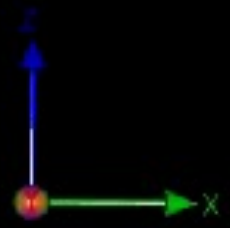


Rhodamine B

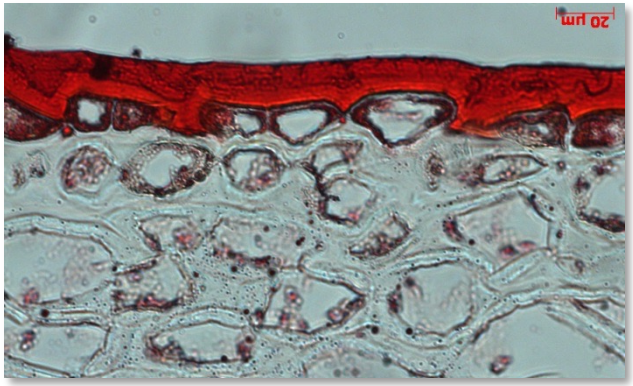
Tomato Fruit Cuticle Architecture

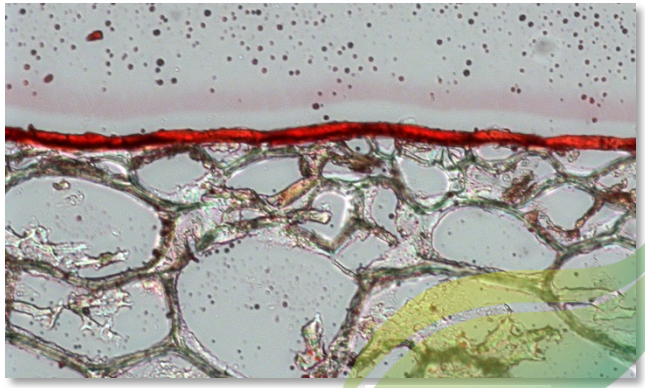


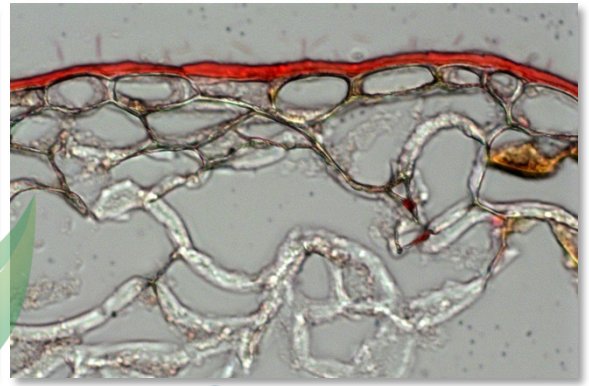

cultiva®


Z
X

Diverse cuticle structures and compositions



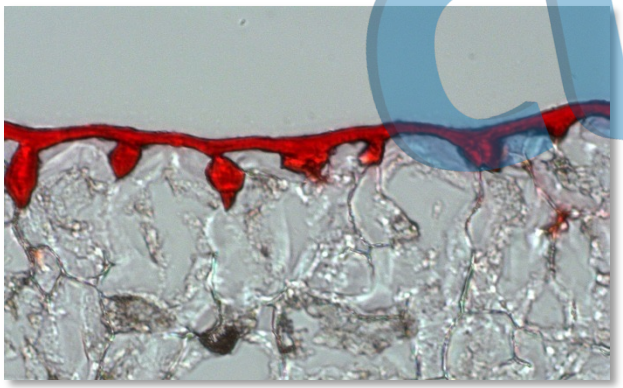


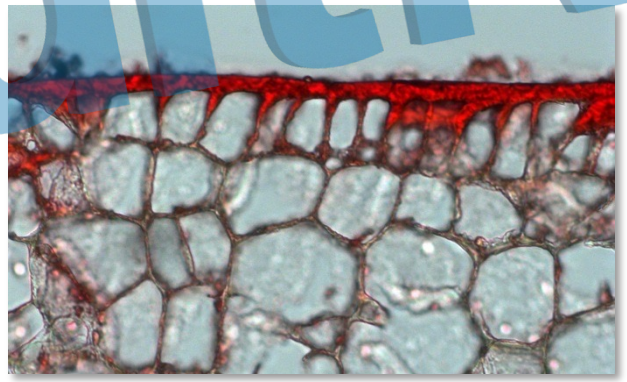


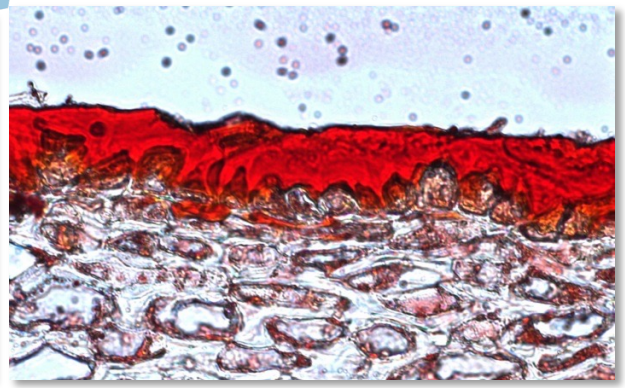
Apple

Grape

Cherry





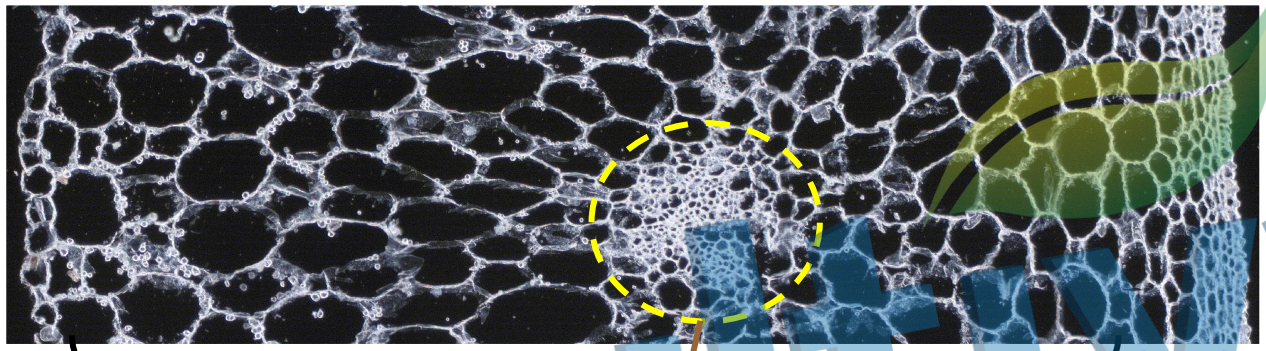


Nectarine

Avocado

Mango

A scalpel not a hammer…



Inner epidermis (1 cell layer)

Parenchyma (> 16)

Vascular tissue

Collenchyma (3 - 5)

Outer epidermis (1 cell layer)

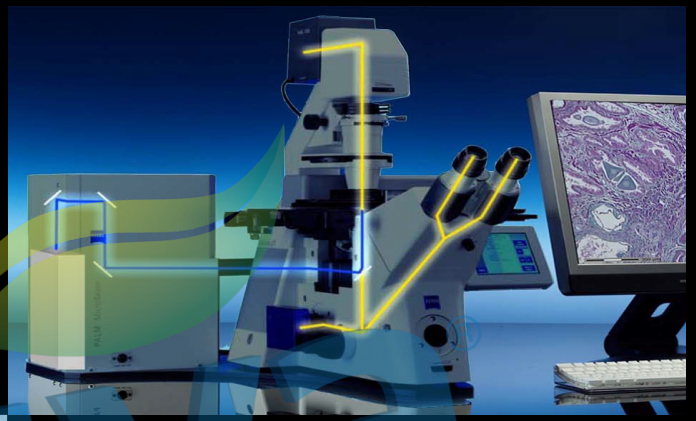
- Significant dilution effects

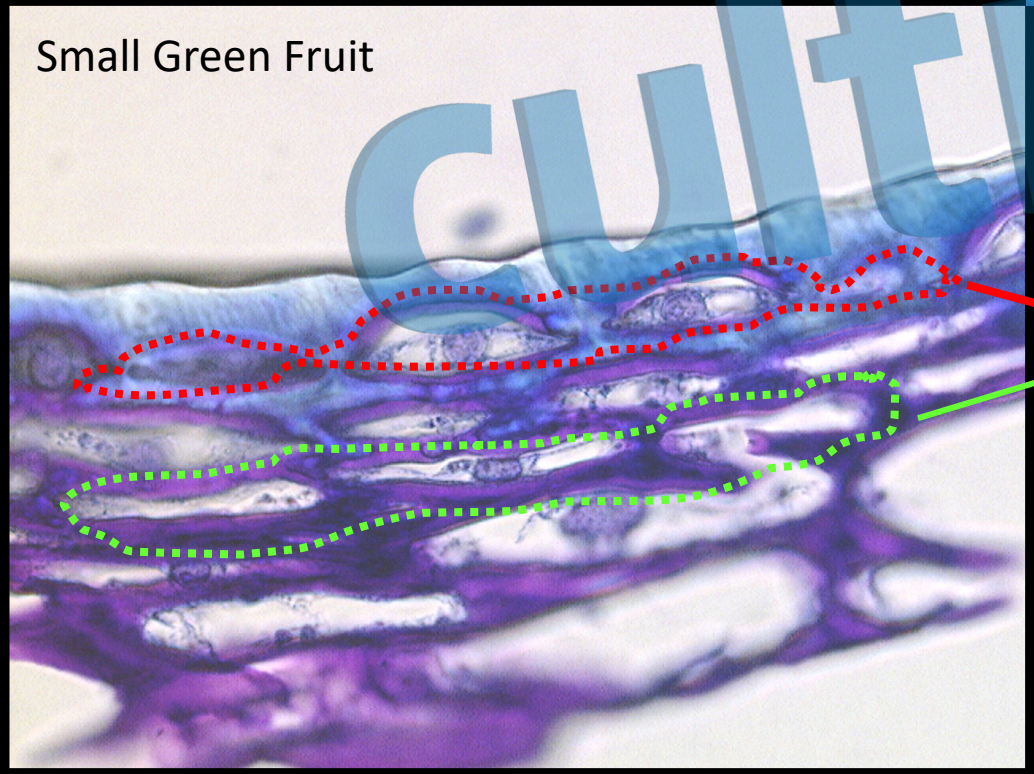
- Loss of valuable spatial information:
  - biochemical pathways
  - regulatory networks

A Platform for Cell/Tissue-Specific Biology

Laser Microdissection (LM)

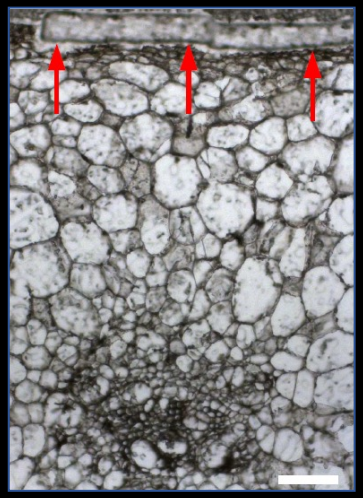
- UV-C laser, spot size < 1 micron
- No contact capture



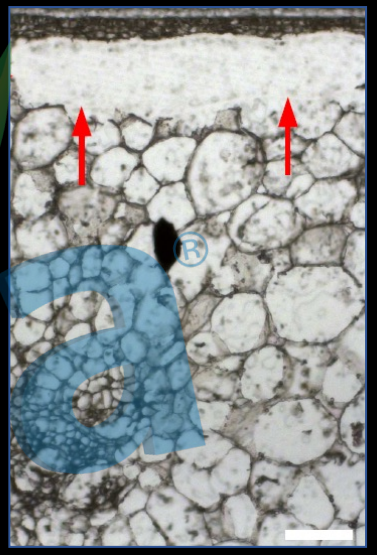


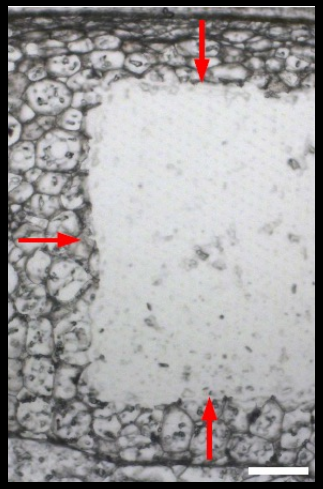
- Transcripts (RNA-seq)
- Proteins
- Cell wall polymers
- Metabolites

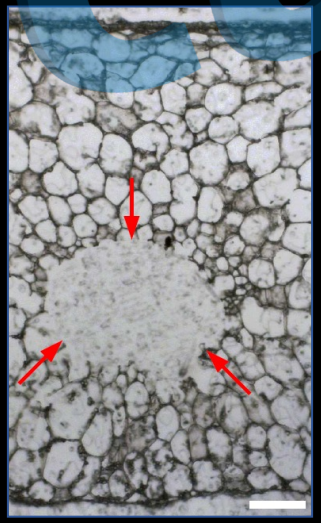
Laser Capture Microdissection

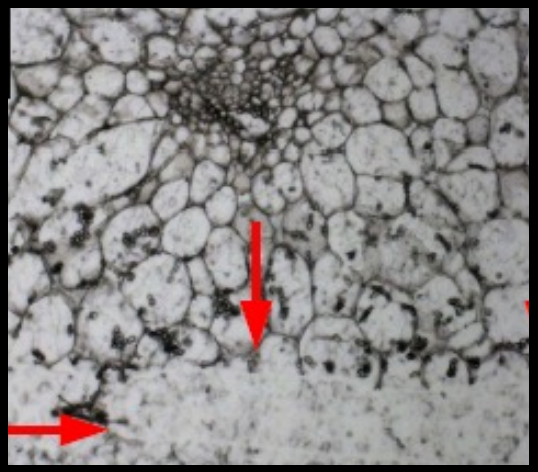


Small green fruit







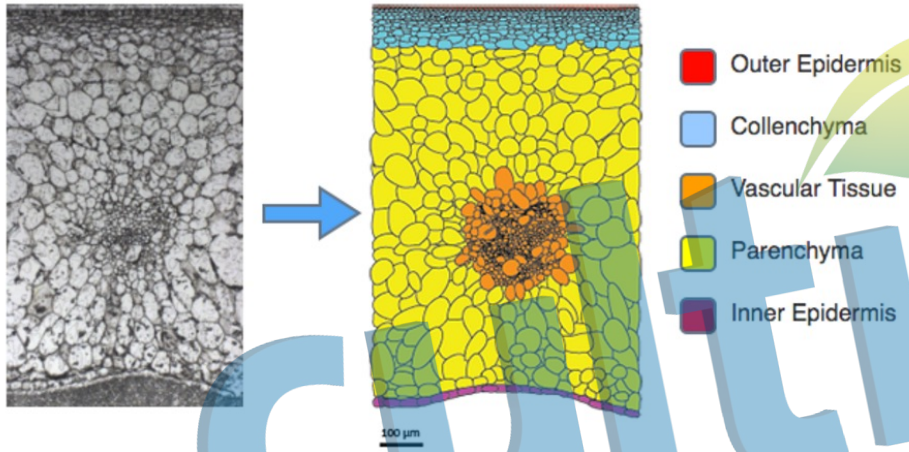


- Transcripts
- Proteins
- Metabolites

Home About Links Contact

Anatomy Viewer

Light Microscopy & Drawings



Browse detailed drawing from light microscopy images of tomato fruit.

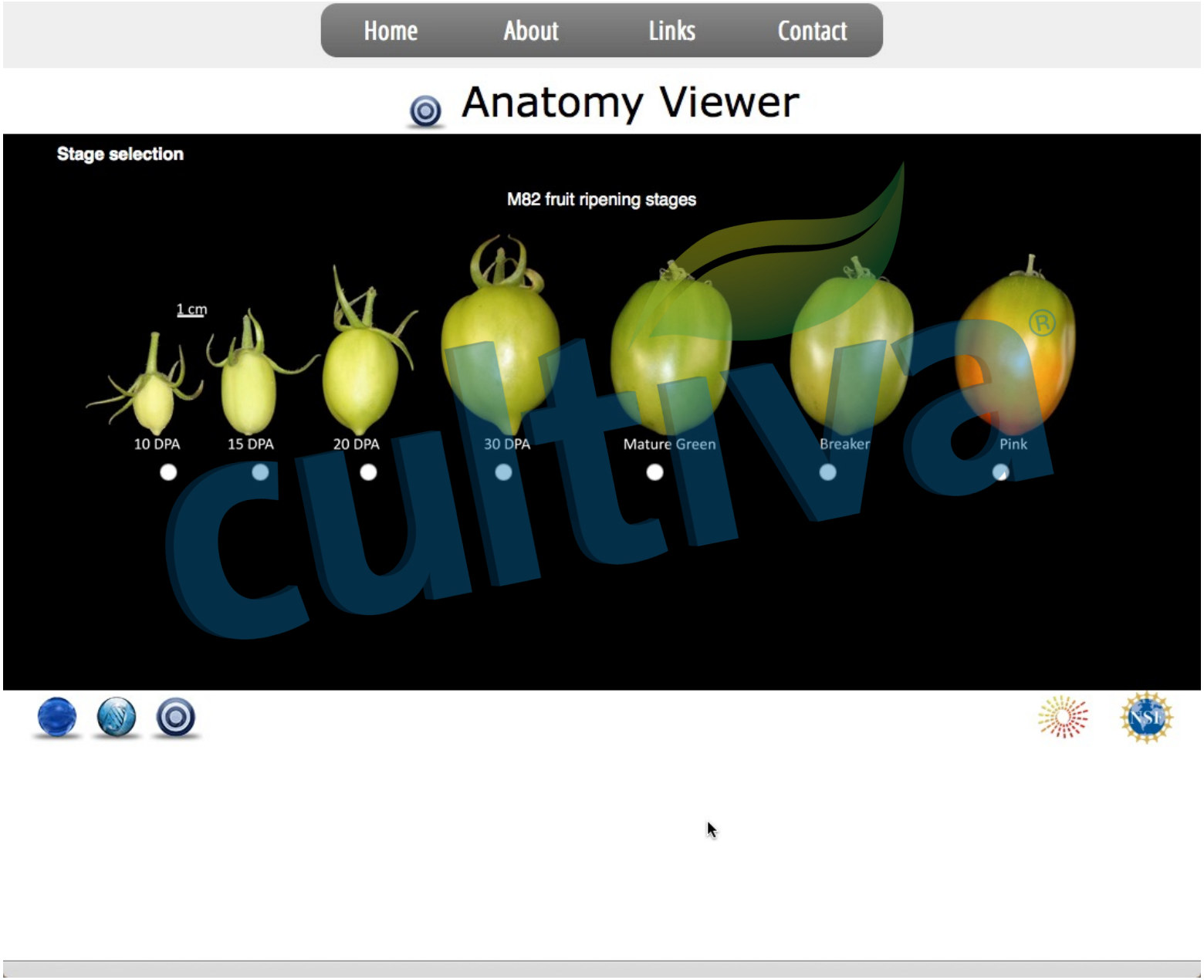
Computed Tomography images & videos

Two-dimensional (2D) Images

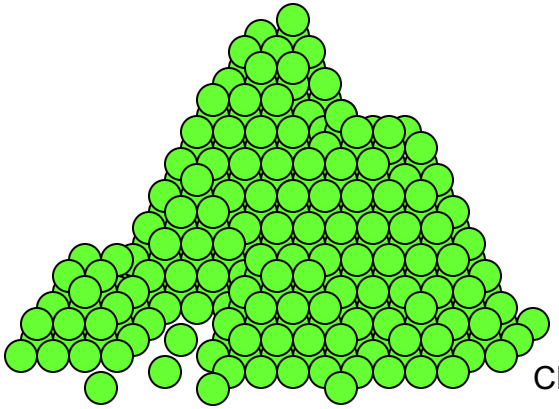
- Cell/tissue-types corresponding to expression data

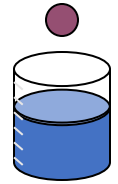
Three-dimensional (3D) Images

Computed Tomography…towards 4D



Analysis of the Tomato Fruit Cuticle Proteins



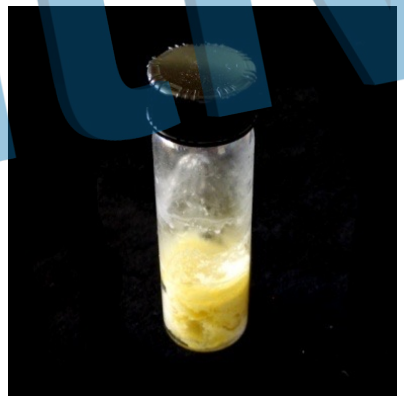


$CHCl_3$/MeOH
(2:1)

Lyophilize

Mass
Spectrometry

~ 50 kg immature
green tomatoes



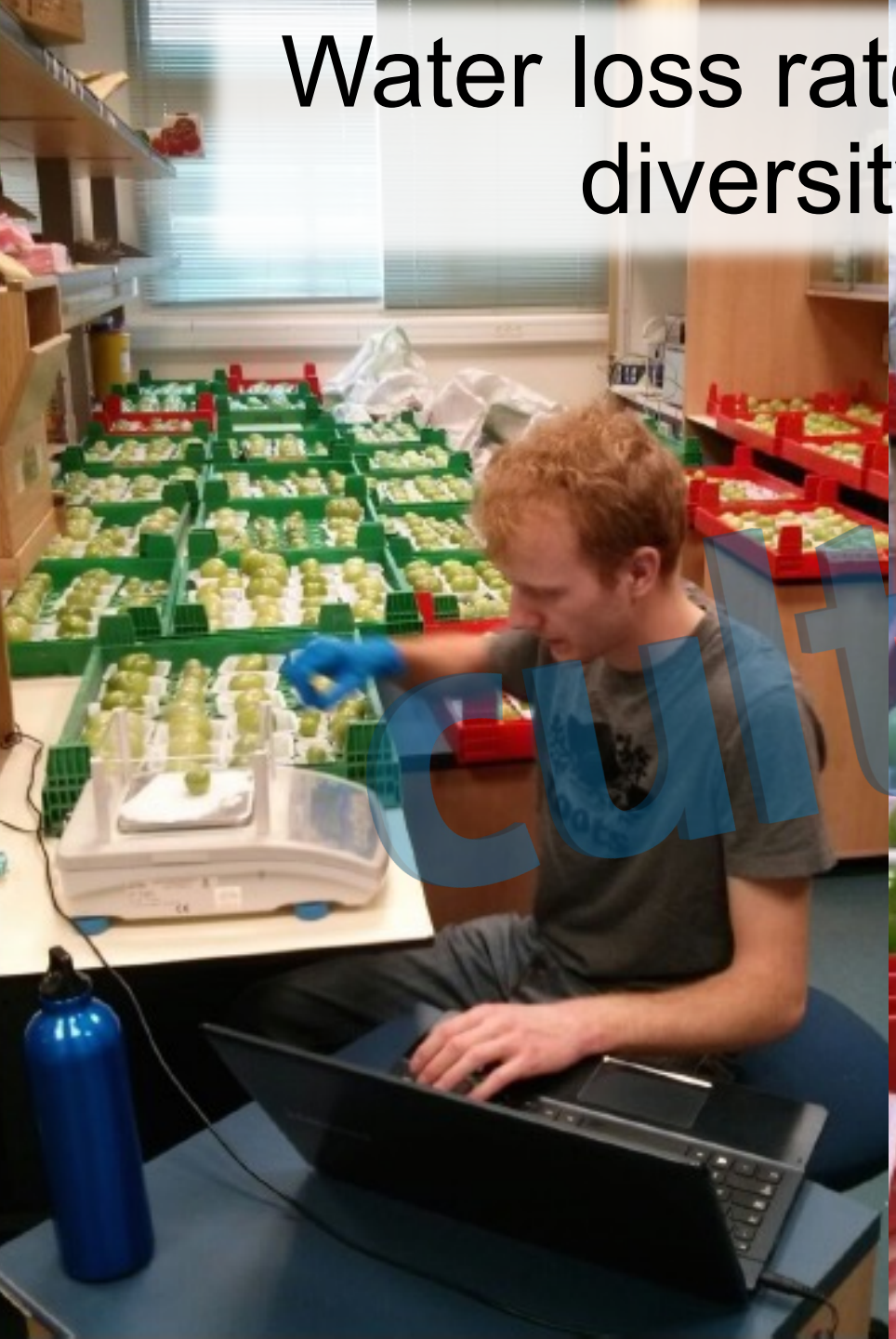
~ 4 g wax

~100 µg
protein

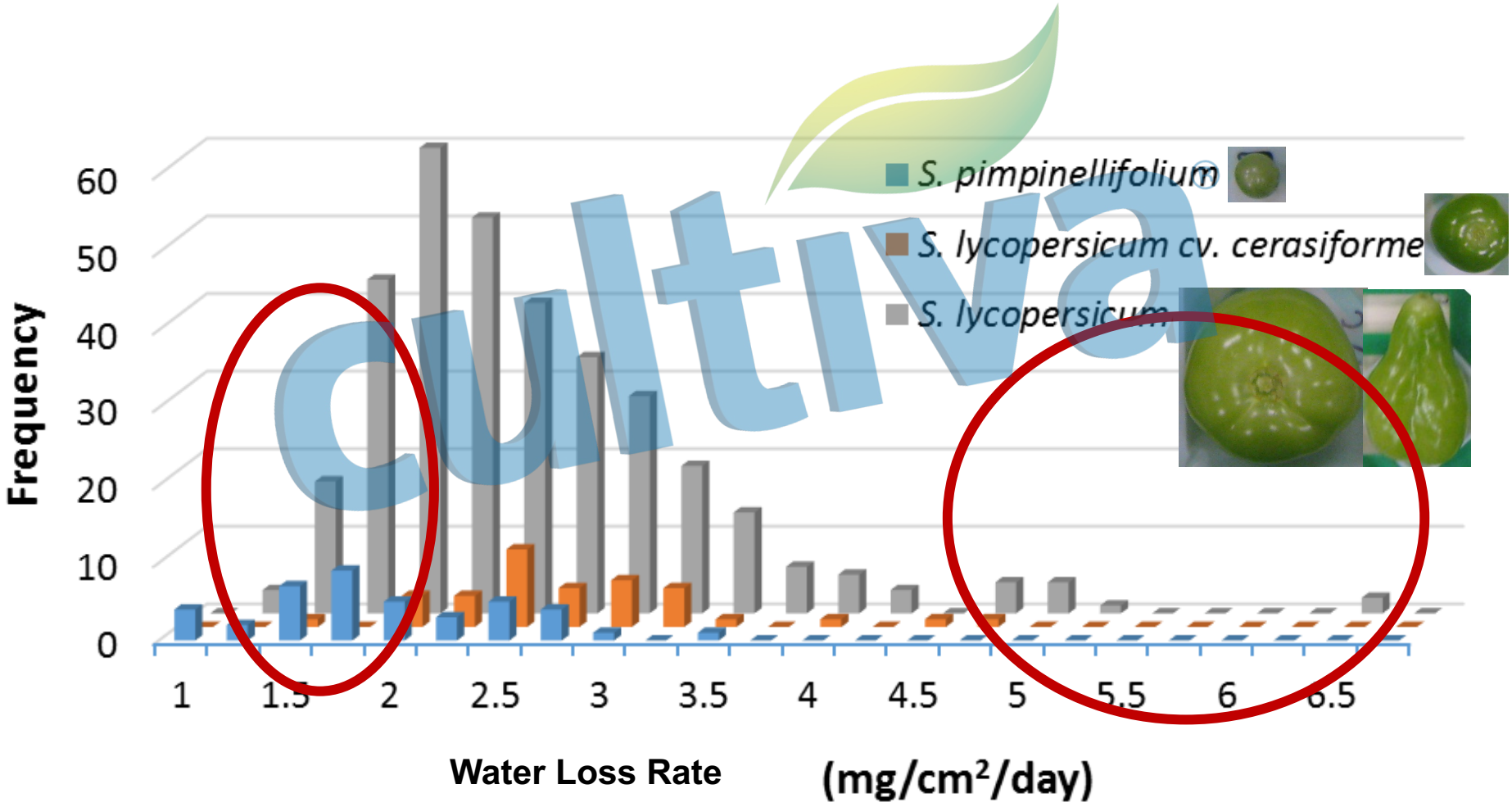
- 202 distinct proteins
- possible cuticle biosynthesis candidates

Serendipity- you get lucky!
Water Permeability: How and Why?

Water loss rates in a tomato diversity panel



Water loss rates vary…but why?

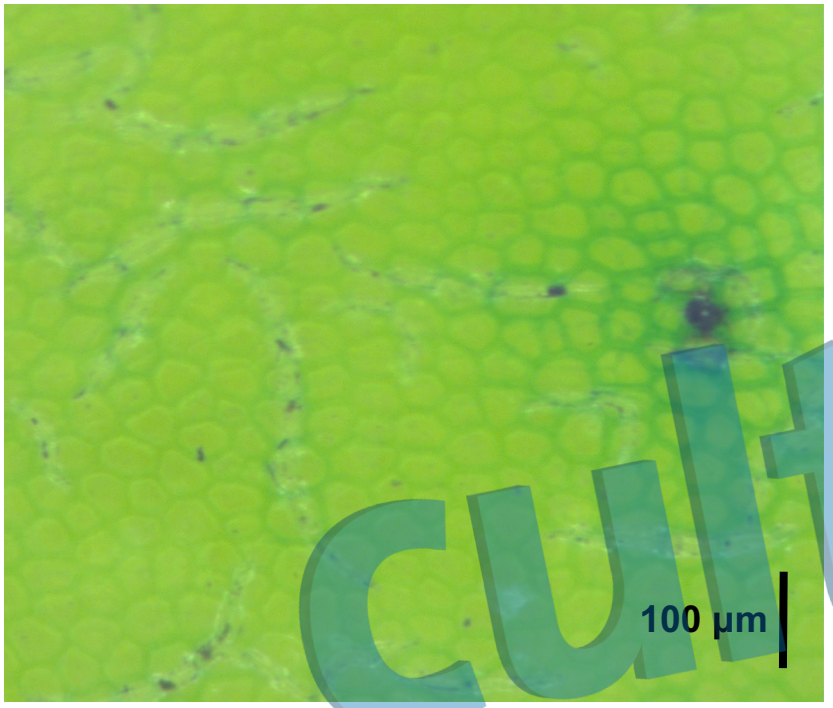


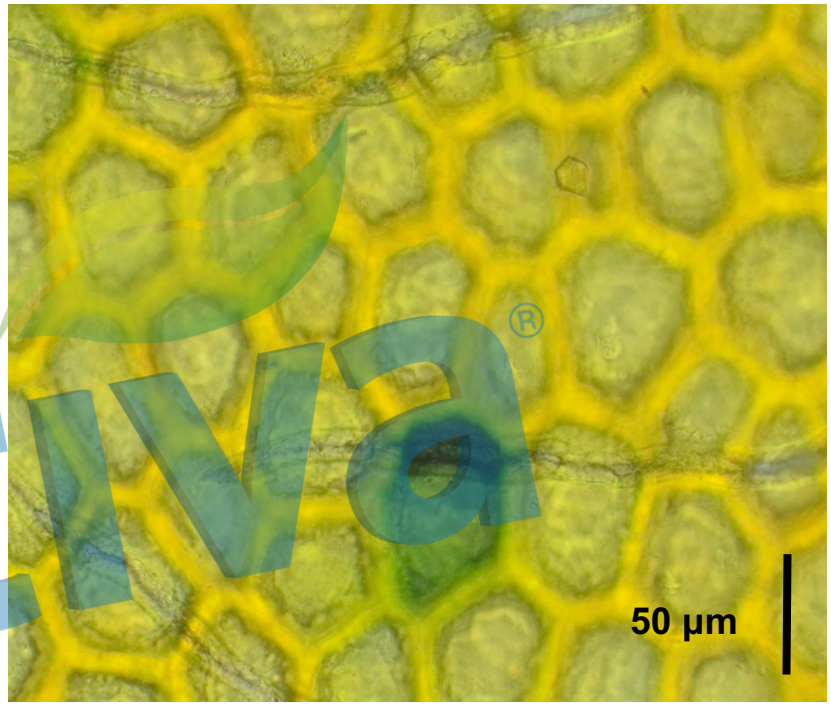
Some fruit have cuticle micro-cracks

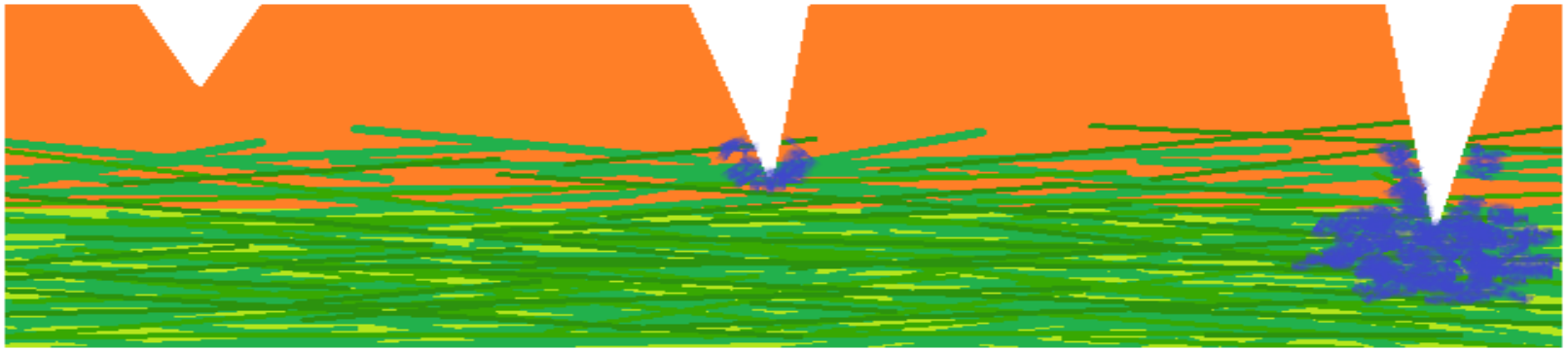
No stain

Toluidine Blue (TB)-stained micro-cracks

Micro-cracks with Toluidine Blue (TB)







A puzzle…

Water loss not related to
- waxes
- cutin
- cuticle thickness

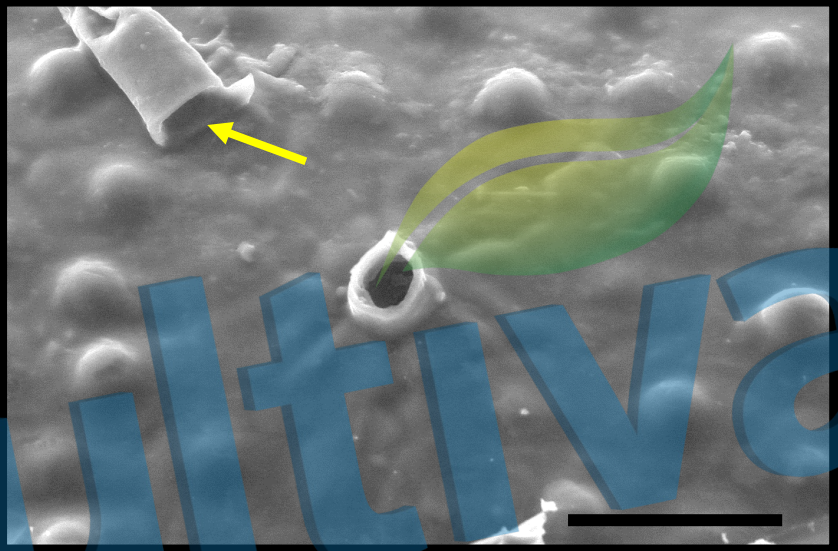
100 µm

TB staining of tomato fruit surface

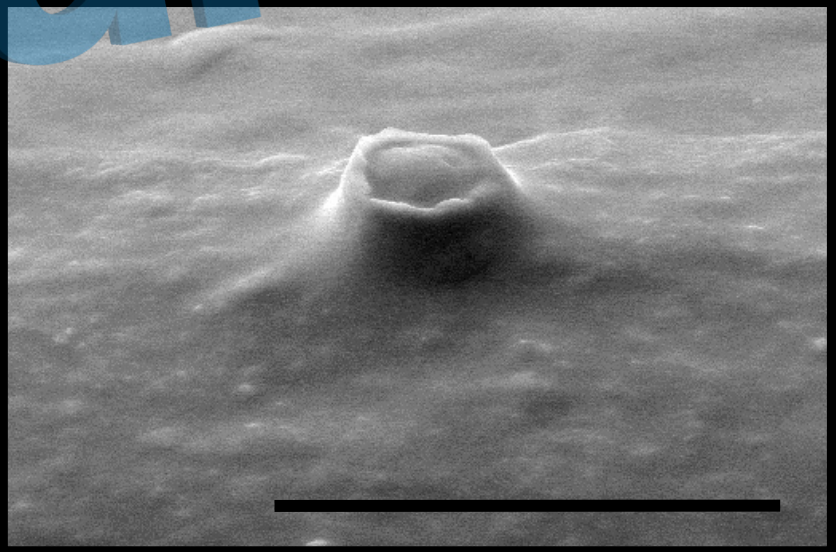

cultiva®

Cuticles repair themselves!

O hours



4 hours later

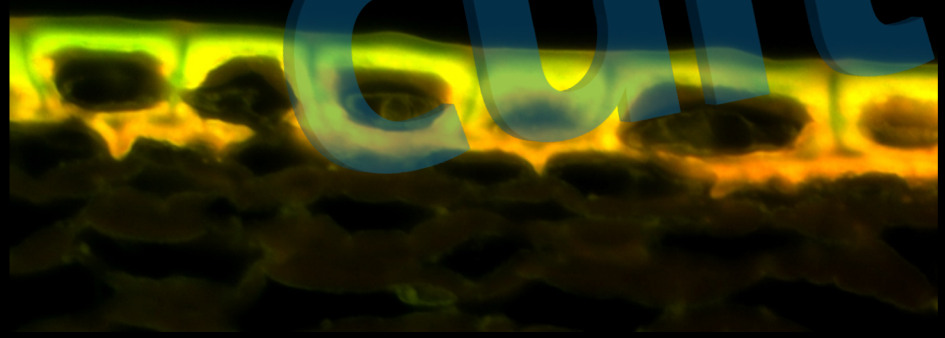


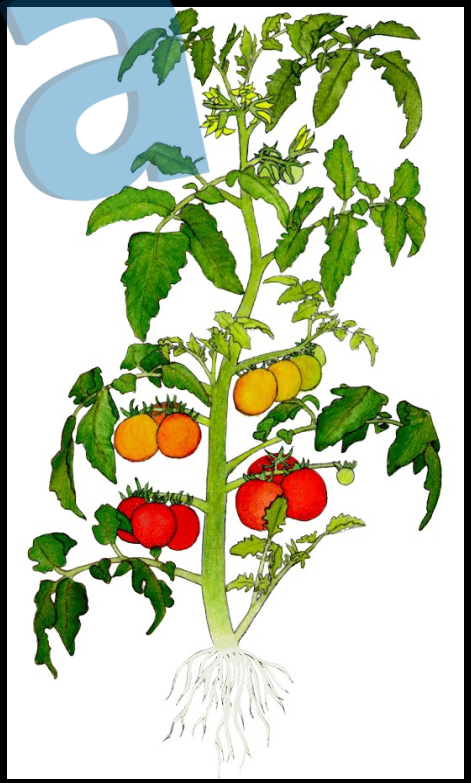
Plant Skins: Summary and Future Questions

- Structures of plant cuticles are highly complex-
- We now have a basic biosynthetic framework

- Big ‘unknowns’: ultrastructure and spatial heterogeneity, structure-function relationships, trafficking and assembly, translational potential.

The cuticle:
A key target to improve crop quality





Developing new technologies to study
and enhance cuticle structure and function

Acknowledgments

Rose lab

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The Cuticle: a Barrier to Fruit and Vegetable Spoilage

- Global losses of fresh produce to pests, pathogens and desiccation during processing, transport and storage can reach 25-50%

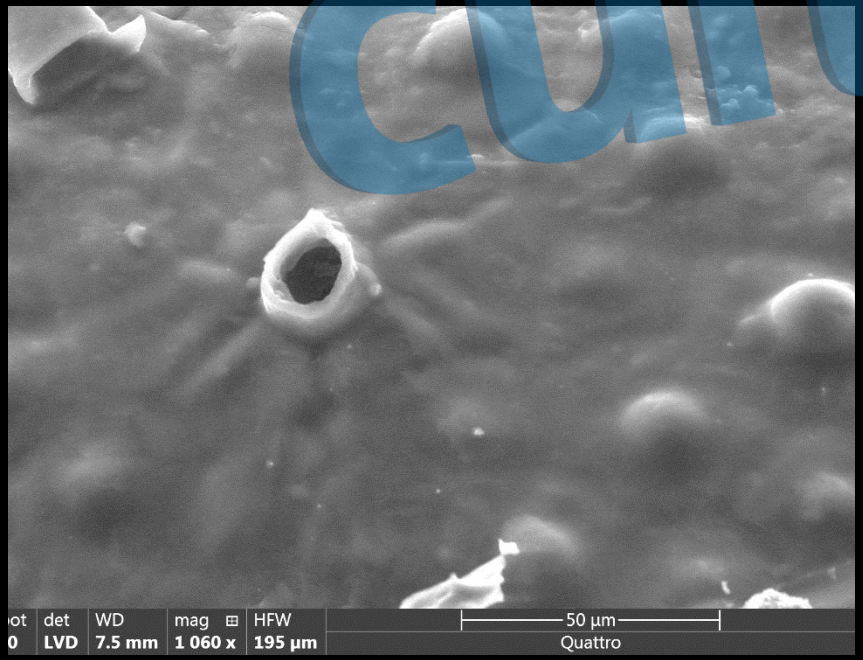
- In the US, supermarket losses can amount to up to 50-60% of some fruits or vegetables

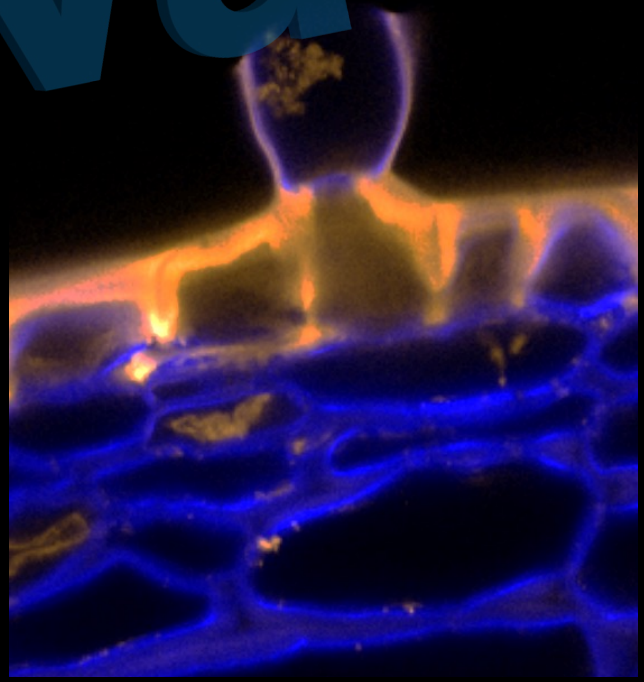
- Annual food production in the U.S. consumes about 120 km^3 of irrigation water

- Approximately 30% of this food is thrown away… corresponds to 40 billion liters of irrigation water

Conclusions

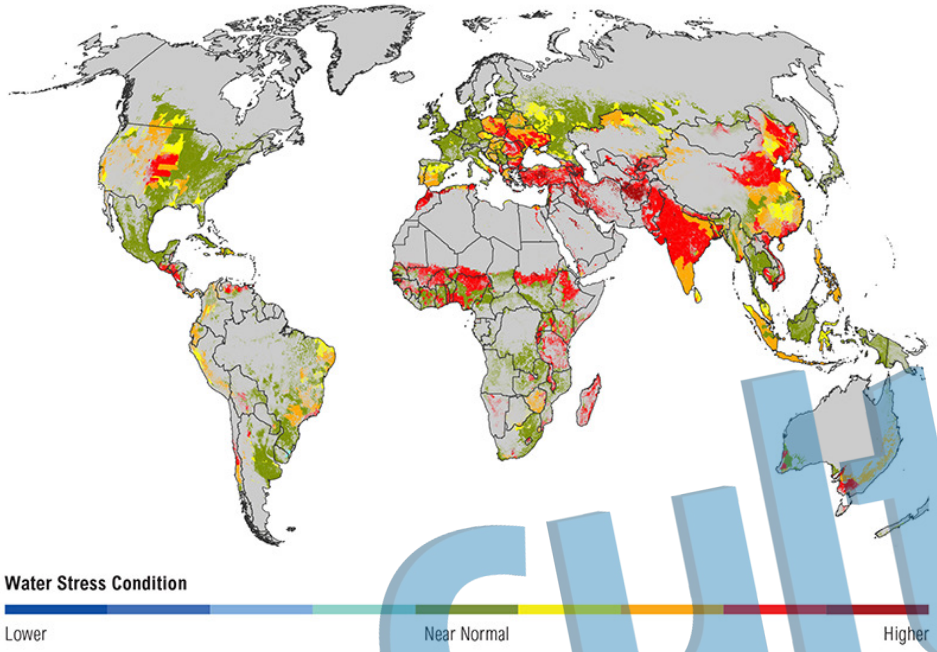
- Cuticles in some cultivars are self-healing
- Cutin deposition and remodeling?





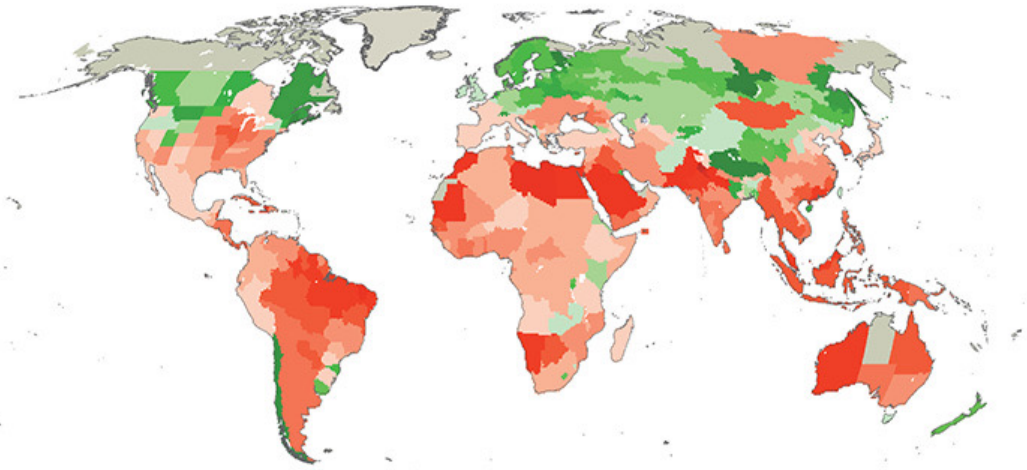
The world is getting hotter and thirstier…

Water stress will increase in many agricultural areas by 2025 due to growing water use and higher temperatures (based on IPCC scenario A1B)



Food security and optimizing water use and efficiency is a critical world-wide socio-economical challenge

Most studies now project adverse impacts on crop yields due to climate change (3°C warmer world)



Big questions:

- Assembly
- Remodeling
- Diversity
- Evolution
- Structure-function relationships