ENS DE LYON

RDP

Towards a quantitative biology of hormone signalling

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The Centre for Plant Integrative Biology
www.cpib.ac.uk

The University of Nottingham
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A quantitative biology?

➔ Provides "real world" data

To parameterise models
To get new insights into developmental processes

➔ Approaches

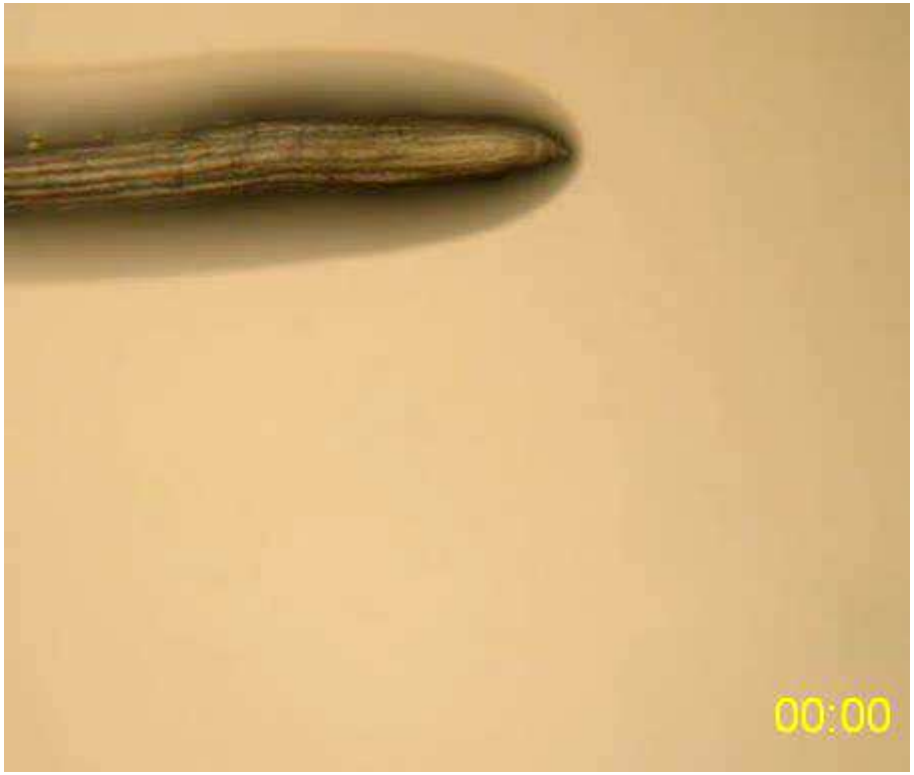
Live imaging ➔ Spatio/Temporal aspect = 4D (x,y,z,t)

Can account for rapid and localised developmental programs

Part 1: New insights into auxin regulation of root gravitropism

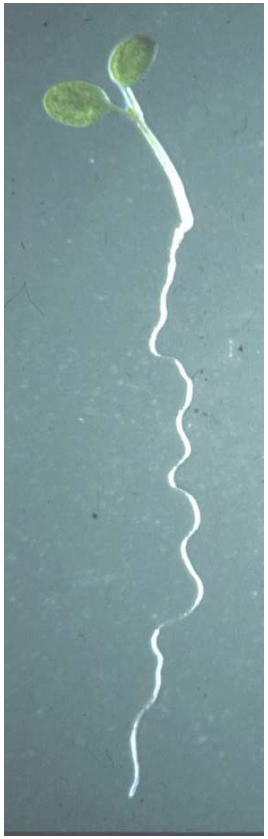
Part 2: A new sensor for jasmonates and its applications

Root gravitropism – Control of root growth following gravity

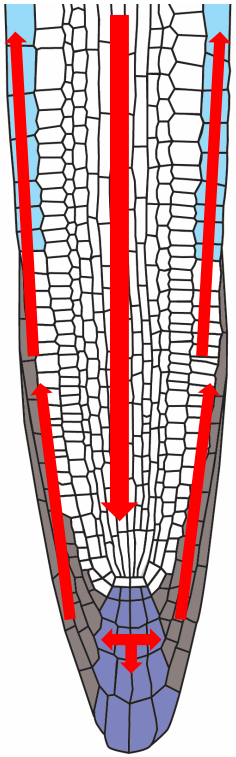


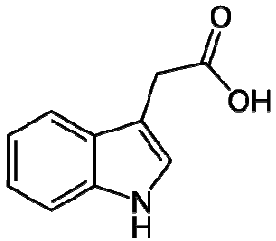
Root gravitropism – Redistribution of auxin drives root bending

WT

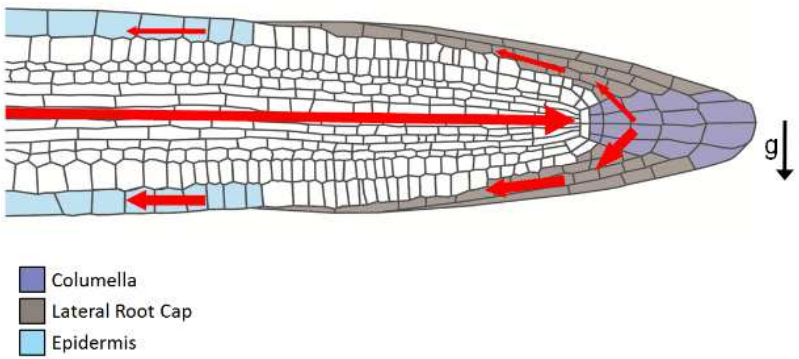


aux1



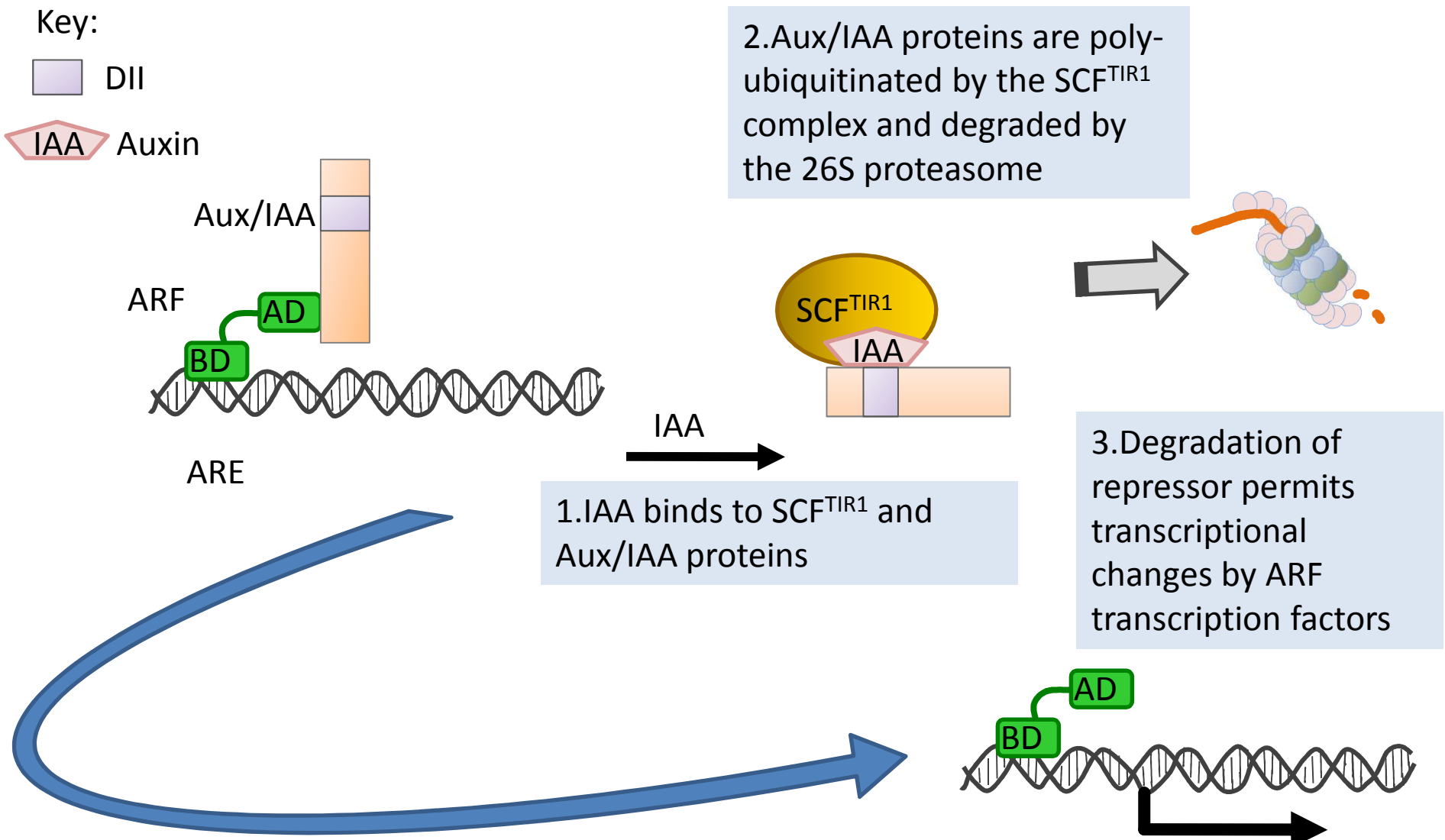


IAA = Auxin



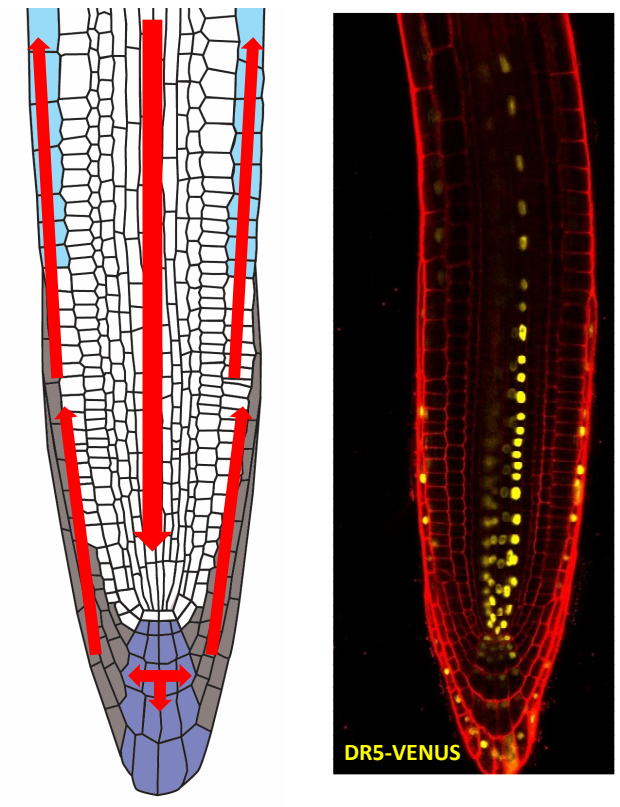
Swarup *et al.* (2013) Book Chapter in *Plant Roots: The Hidden Half*.

Auxin signal transduction pathway

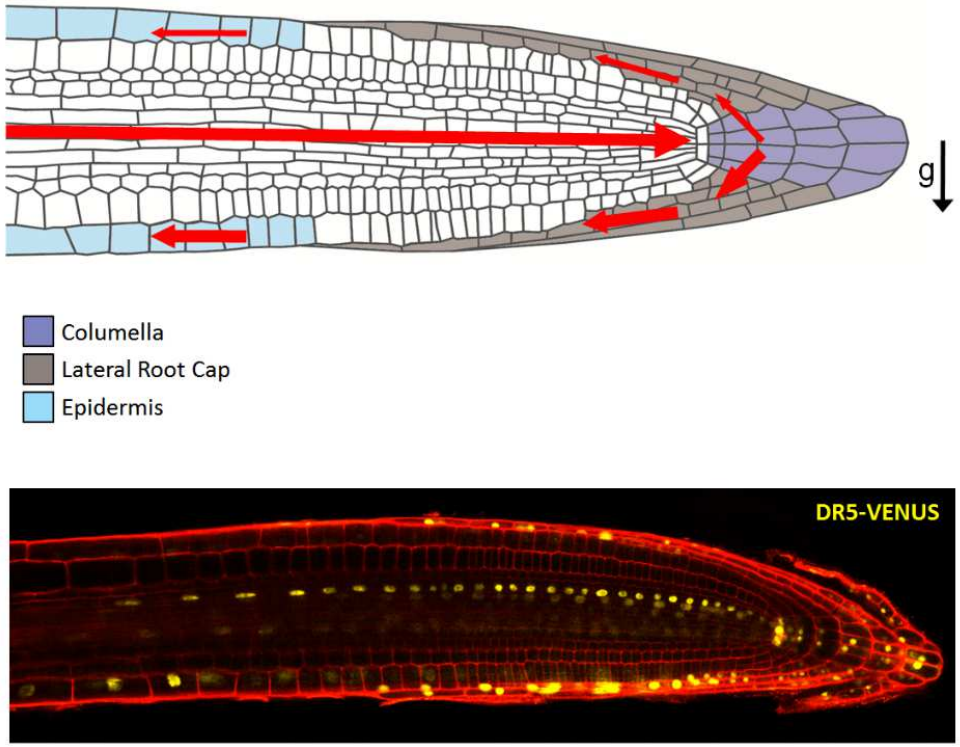


Adapted from The Plant Cell Online

What is the distribution of auxin responses at the root apex?



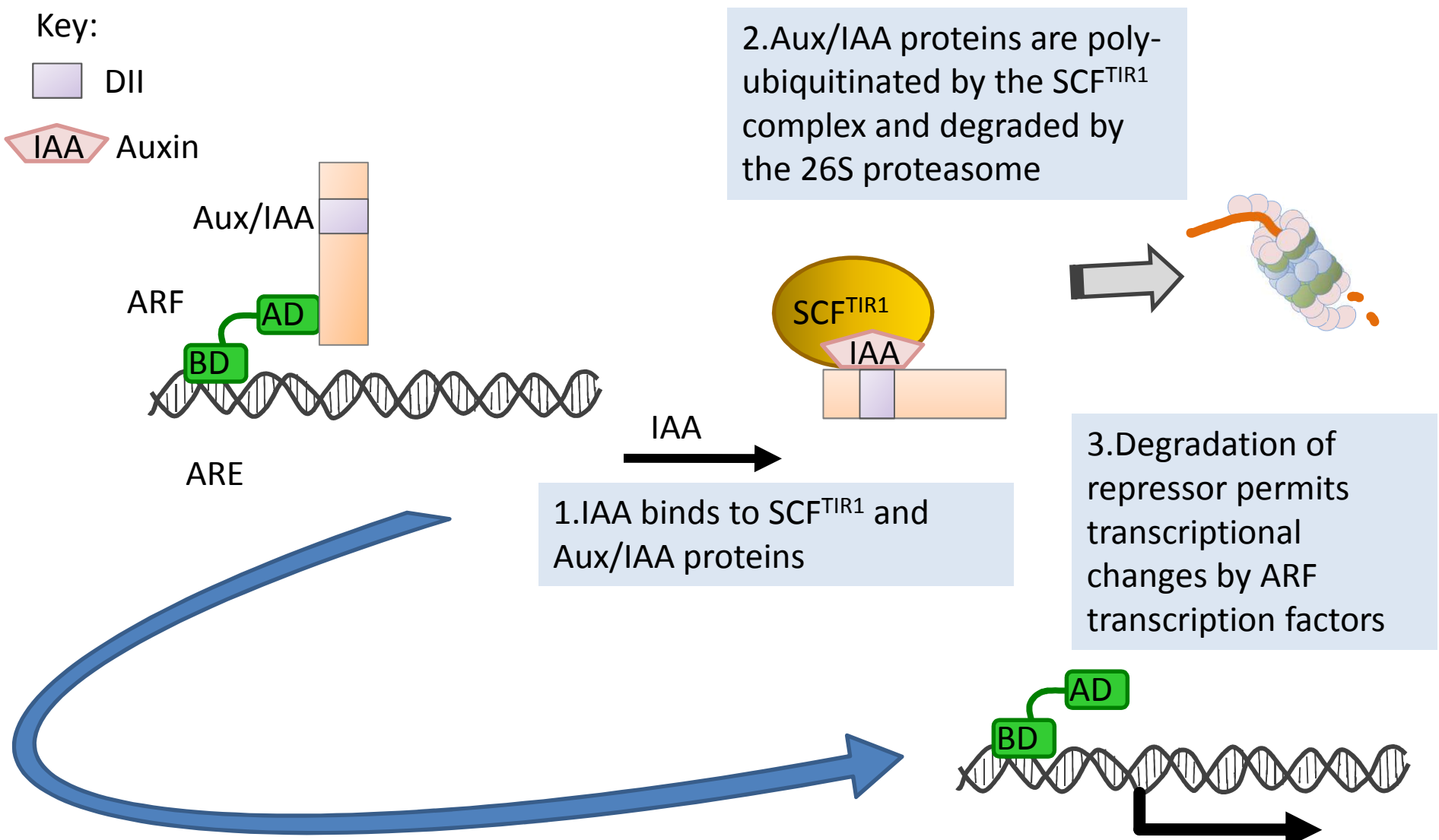
VENUS – fast-folding variant of YFP



3 h after 90° gravistimulus

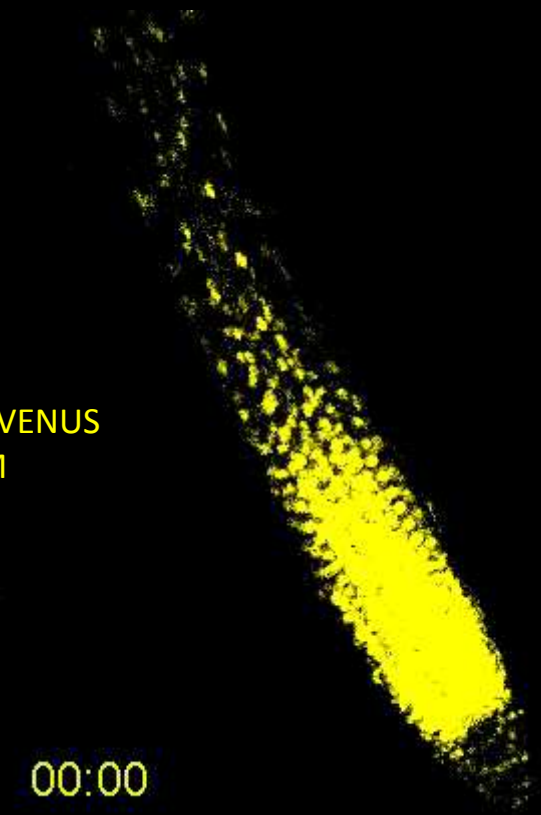
Swarup *et al.* (2013) Book Chapter in *Plant Roots: The Hidden Half*.
Band *et al.,* (2011) *PNAS* **12**:4668-73
Brunoud *et al.,* (2012) *Nature* **482**:103-106

Auxin signal transduction pathway

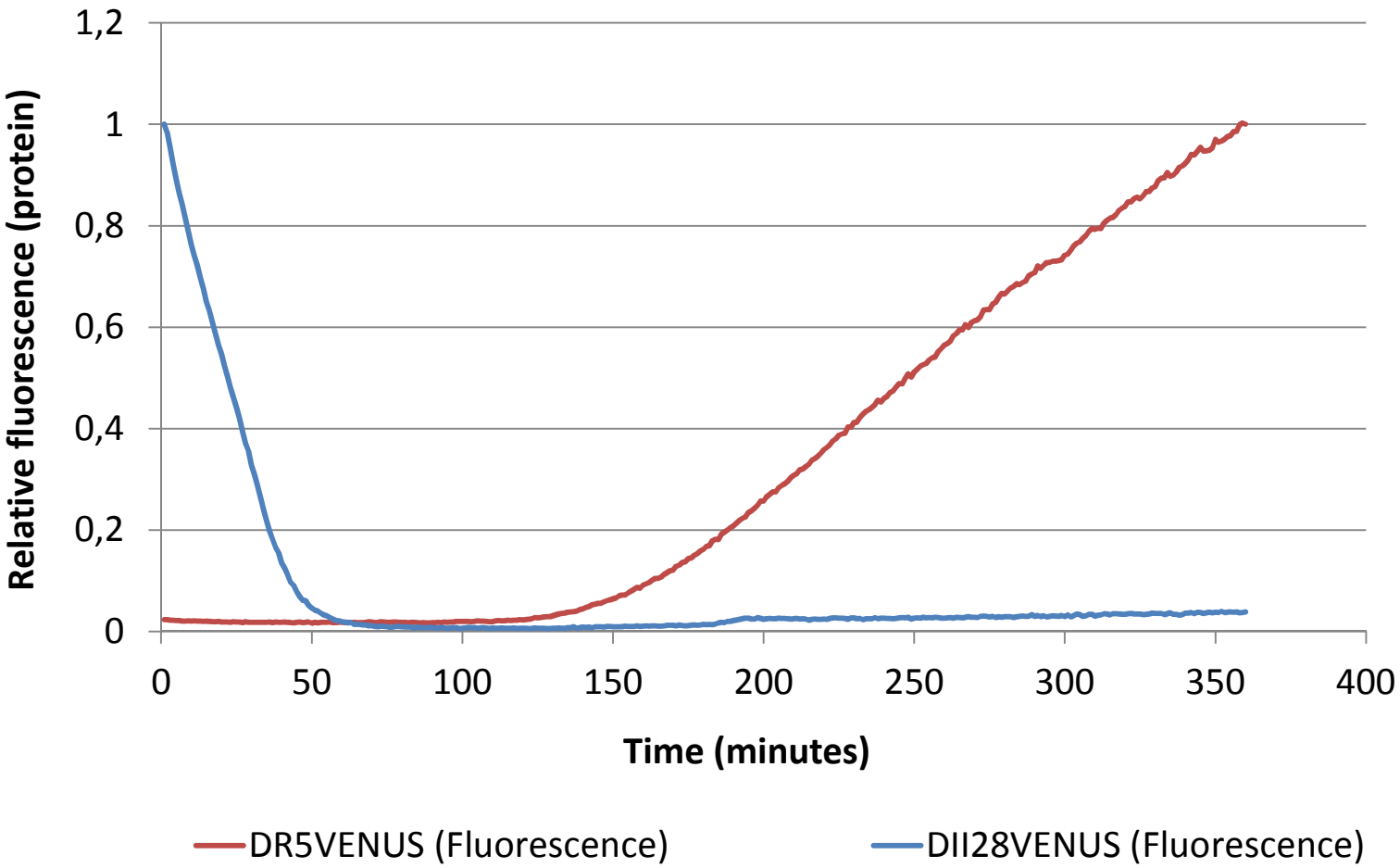


Adapted from The Plant Cell Online

DII-VENUS responds within minutes after auxin treatments



DII-VENUS degradation correlates with transcriptional activation of DR5



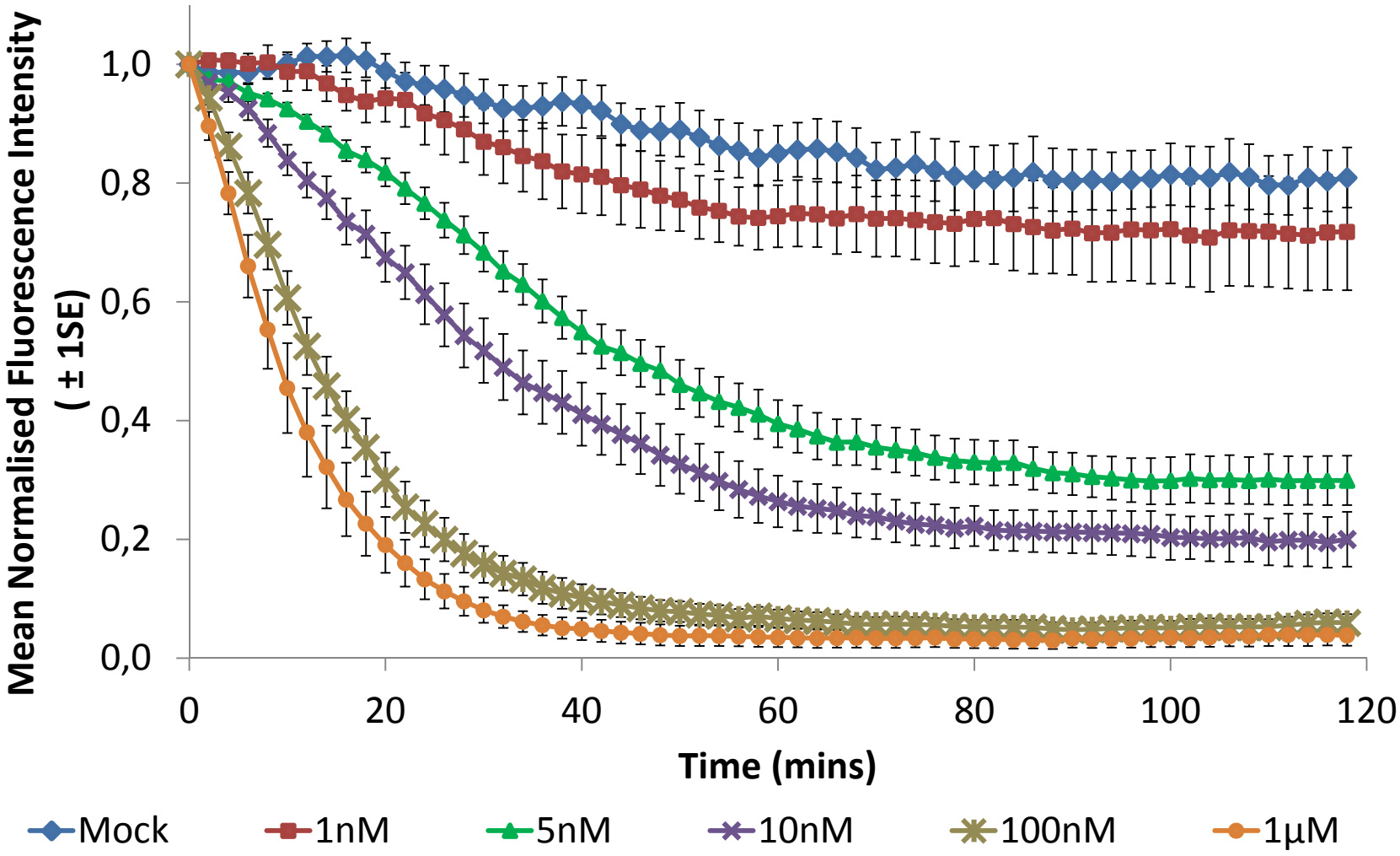
Brunoud *et al.,* (2012) *Nature* **482**:103-106

What are the pre-requisites for a good hormone sensor?

1. is highly selective for its cellular target(s)
2. responds rapidly to physiologically relevant concentrations
3. does not disturb endogenous systems
4. has a response that can be calibrated and quantified
5. is easily monitored

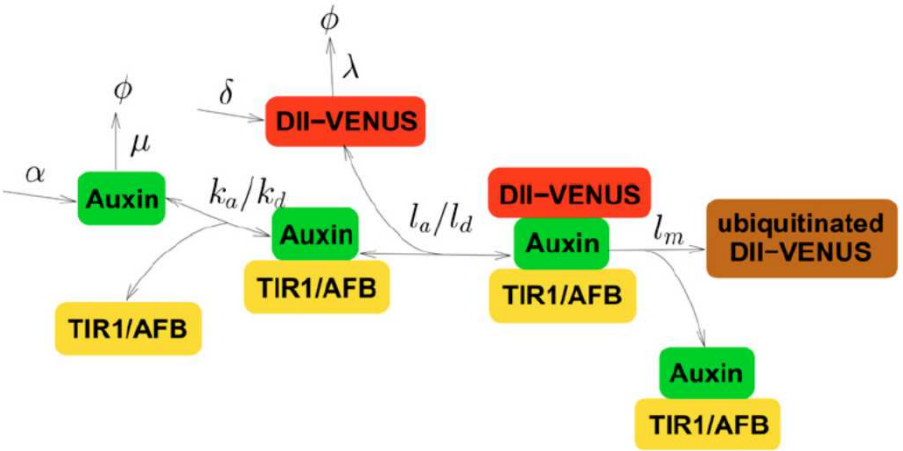
Wells *et al.* (2012) *TIPS*

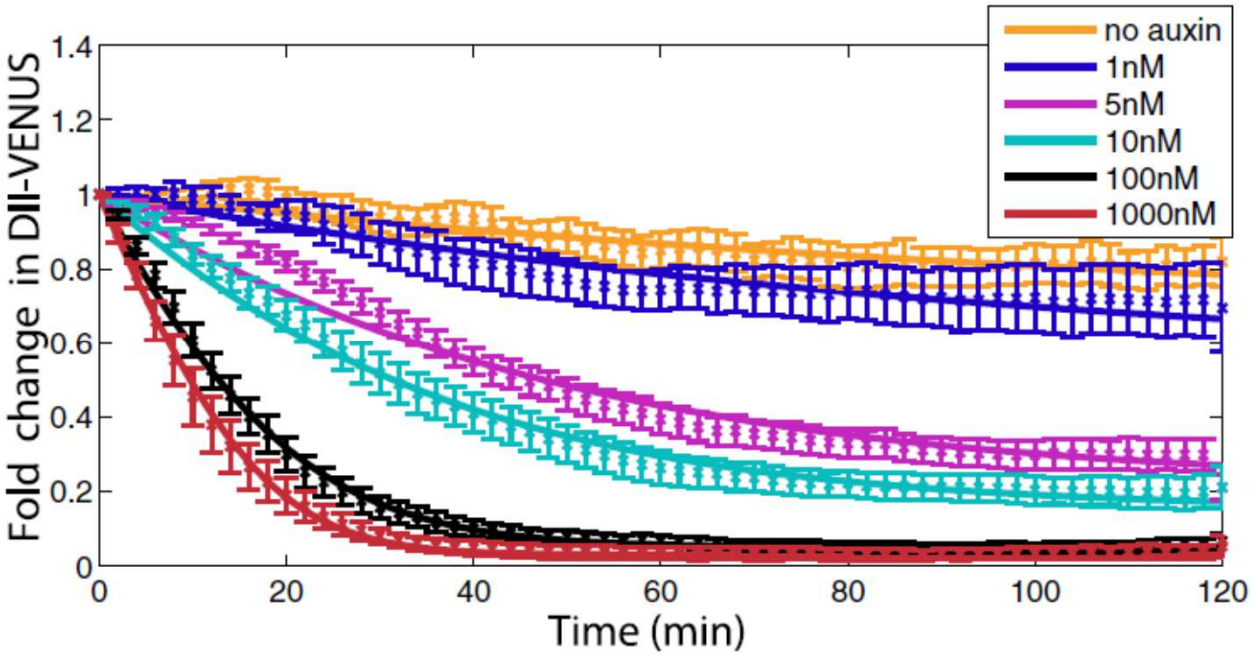
DII-VENUS responds rapidly to a relevant range of auxin concentrations



Band *et al.*, (2011) *PNAS* **12**:4668-73

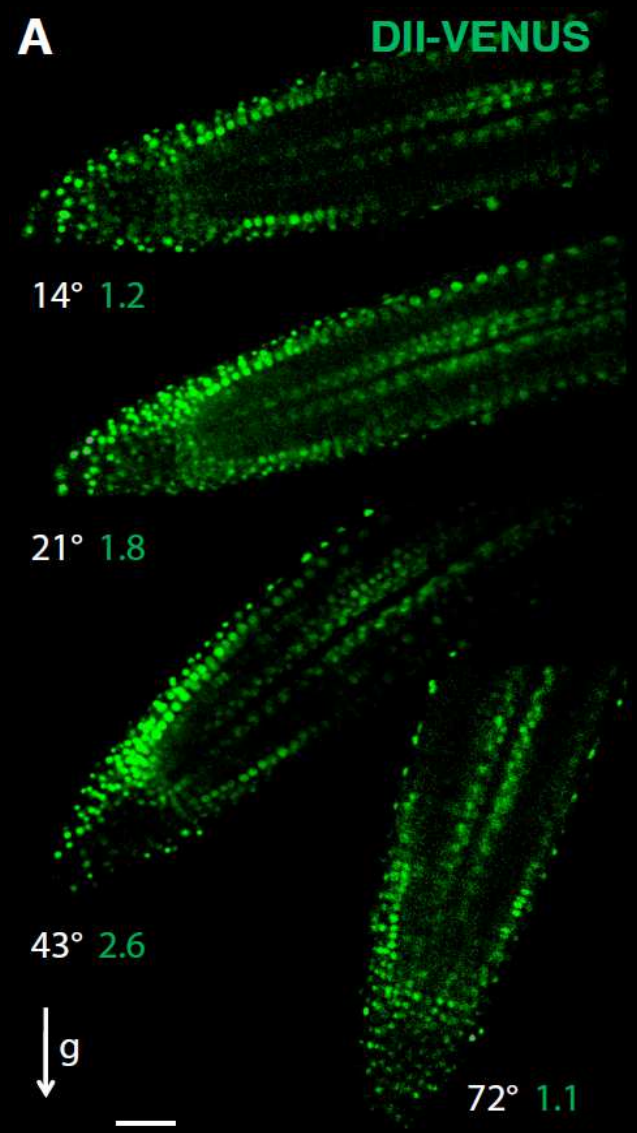
A model consisting of a single ODE was used to fit the dose-response curves

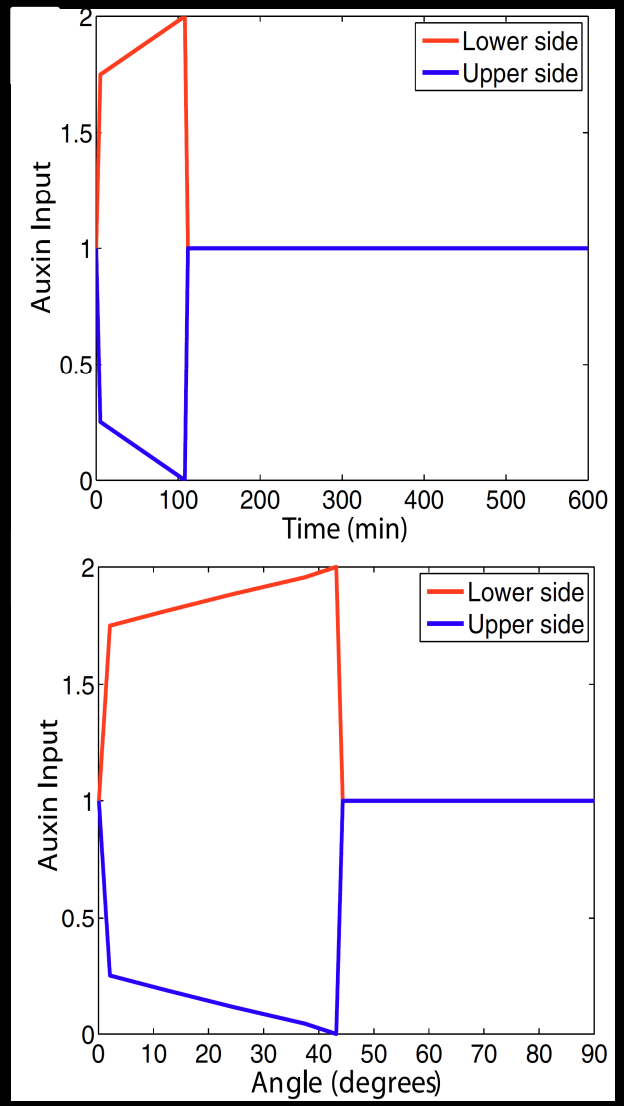




Band *et al.,* (2011) *PNAS* **12**:4668-73

DII-VENUS fluorescence changes rapidly during the gravitropic response





Band *et al.*, (2011) *PNAS* **12**:4668-73

A parameterised model of auxin signalling allowed to:

1. Relate VENUS fluorescence with an amount of auxin despite their relationship not being linear

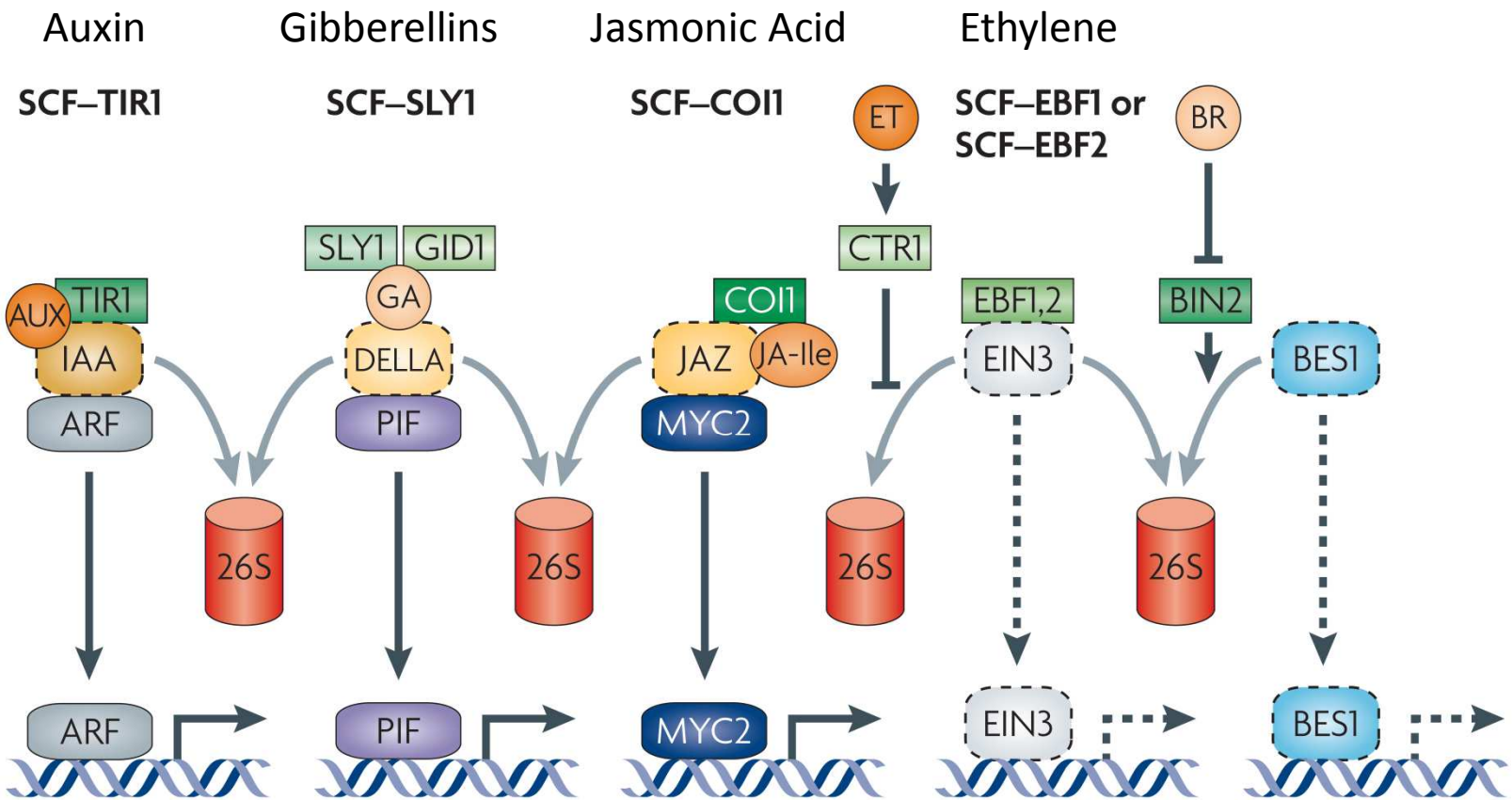
2. Demonstrate new insights into the gravitropic response: a transient redistribution of auxin that depends on the angle of the root with the gravity vector

Importantly, a similar approach (combination of measure DII-VENUS fluorescence and mathematical models) allowed to study the stability and robustness of phyllotactic patterns (Vernoux *et al.,* (2011) *Mol. Sys. Biol.* **7**: 508)

Biosensor design

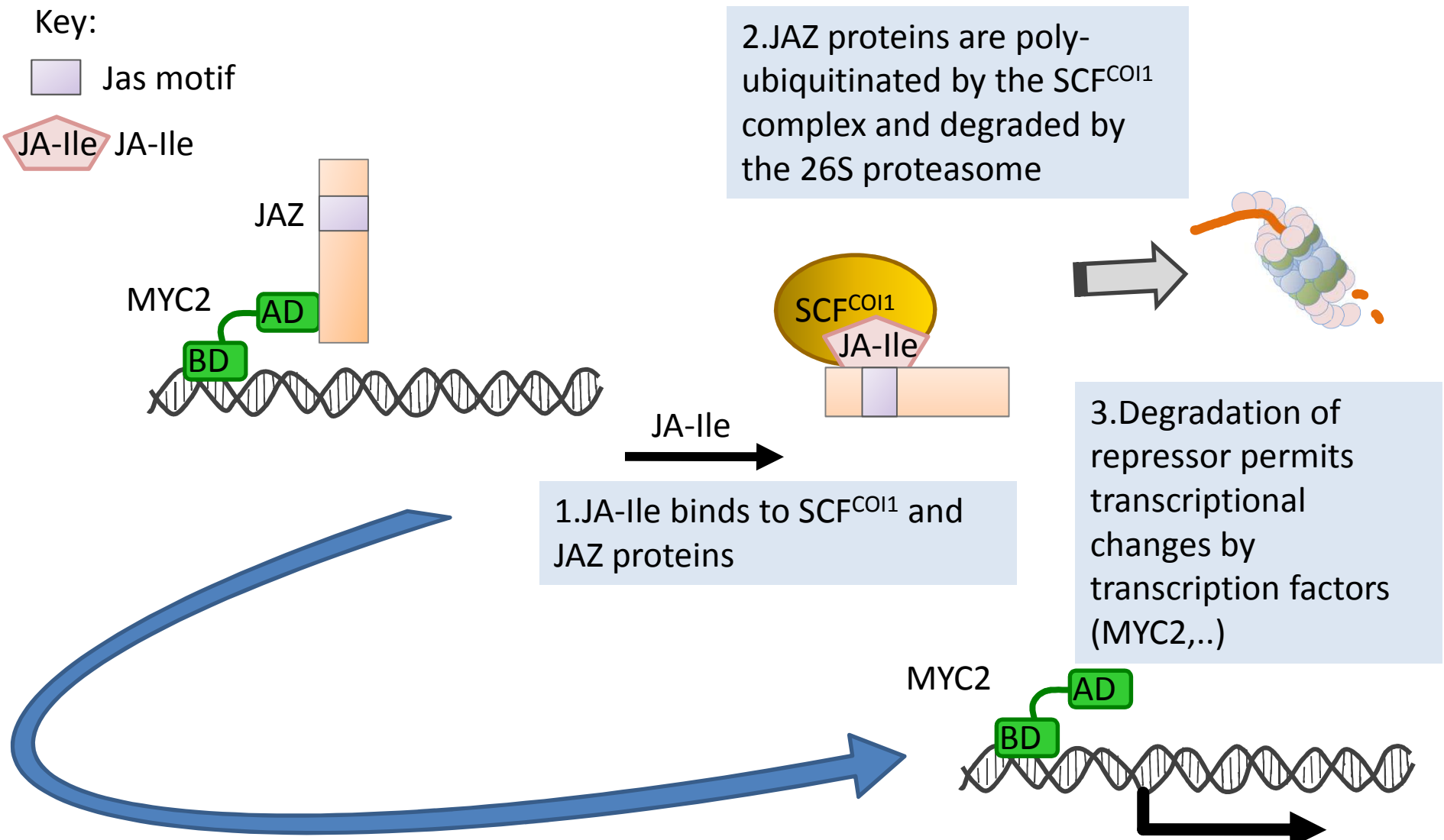
Can the principles and techniques used to develop the DII-VENUS auxin sensor be used to design biosensors for other phytohormones?

Biosensor design



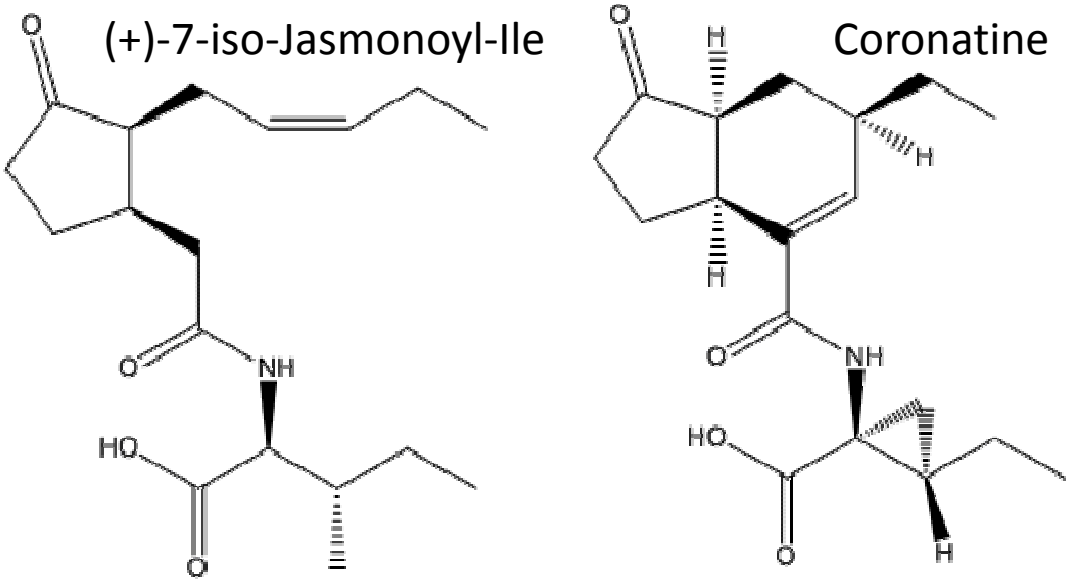
Wolters & Jürgens, (2009) *Nature Reviews in Genetics* **5**:305-17

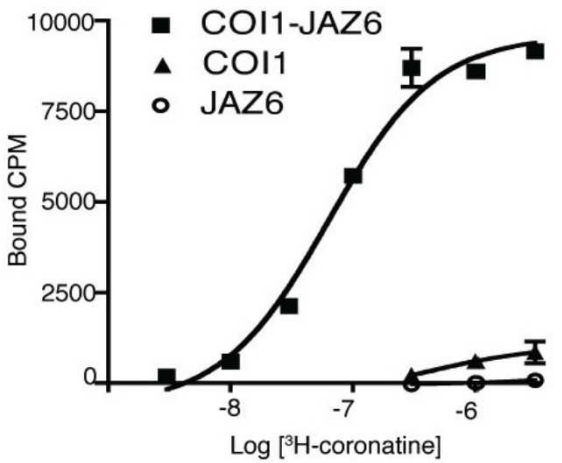
Jasmonic acid signal transduction pathway



Adapted from Plant Cell Online

Coronatine is a potent agonist of JA-Ile





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Wells *et al.* (2012) *TIPS*

JAZ-VENUS is a jasmonate sensor

It is degraded in a dose dependent manner

It is not degraded in presence of non active jasmonates

It is not degraded in presence of MG132 (proteasome dependent)

Targeted mutations to the degron prevents JAZ-Venus degradation

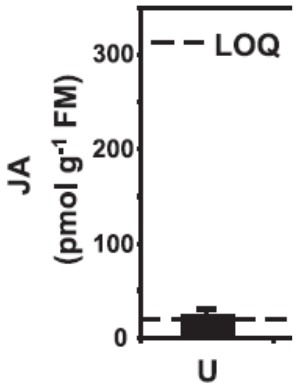
It is not degraded in *coi1-1* (receptor) mutant

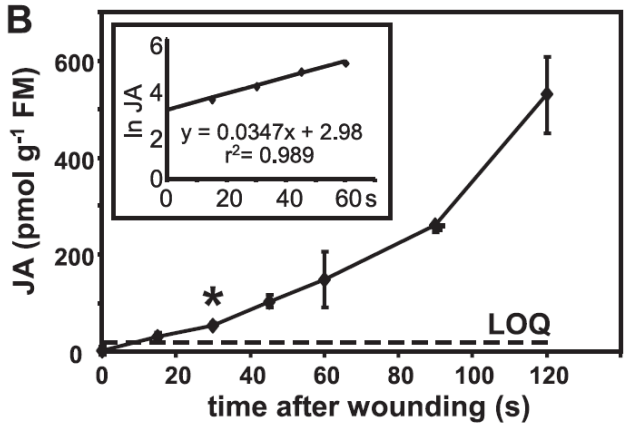
It does not affect the endogenous system

How does the JA sensor behaves during documented responses to jasmonates?

Mechanical wound induces a systemic production of jasmonic acid

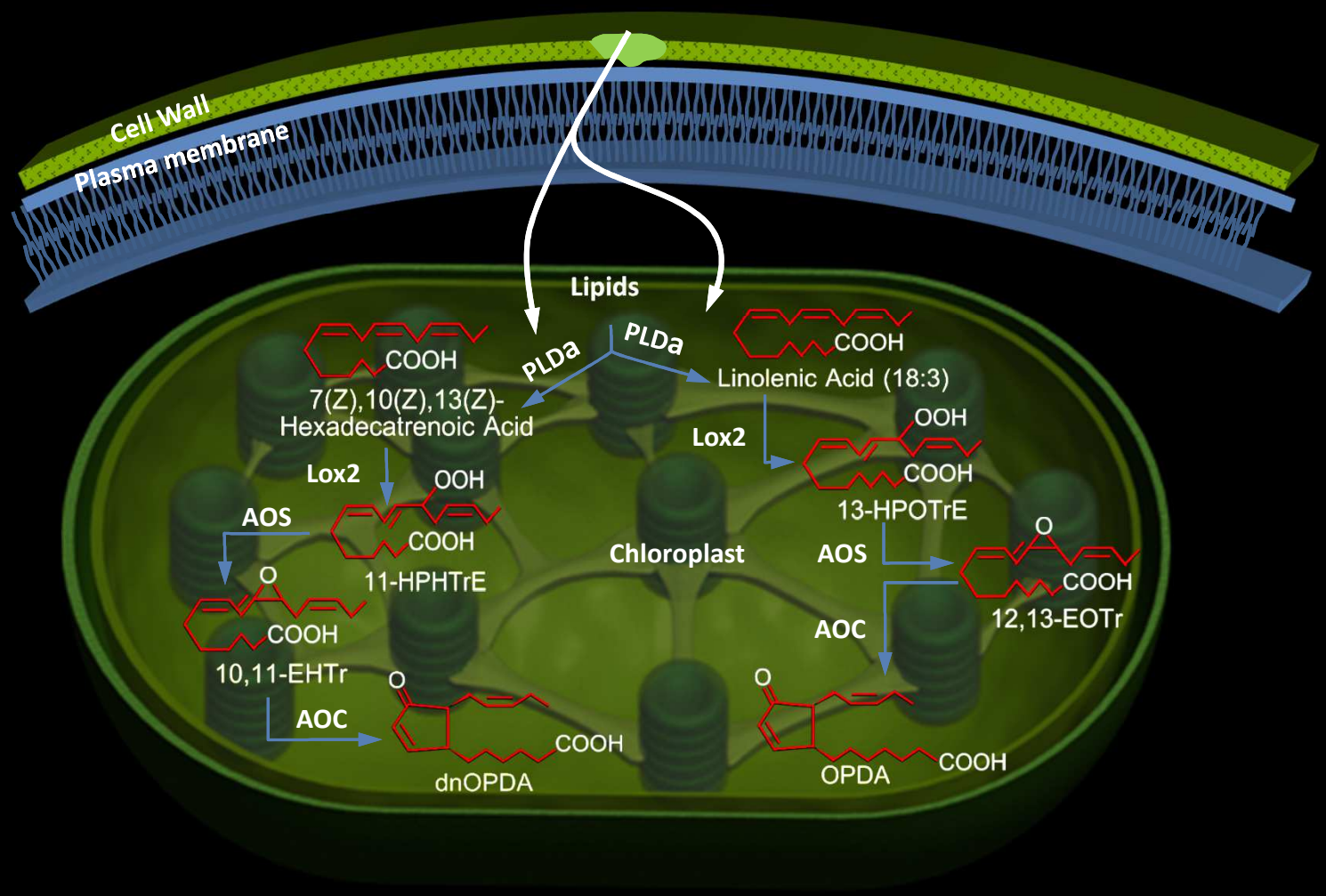
Unwounded plant





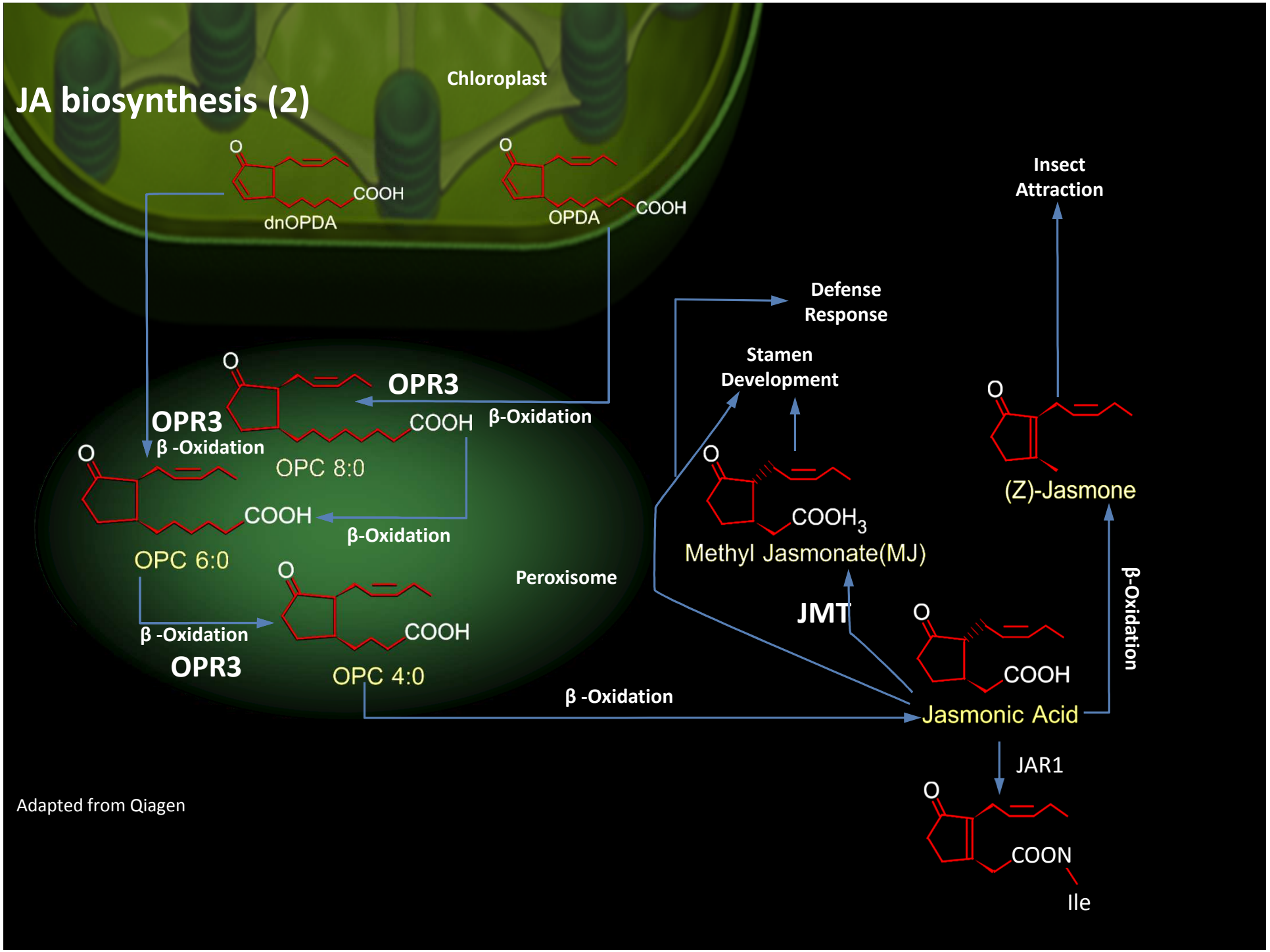
Glauser, G., *et al* (2009) *J Biol Chem* **284**:34506-13

JA biosynthesis (1)



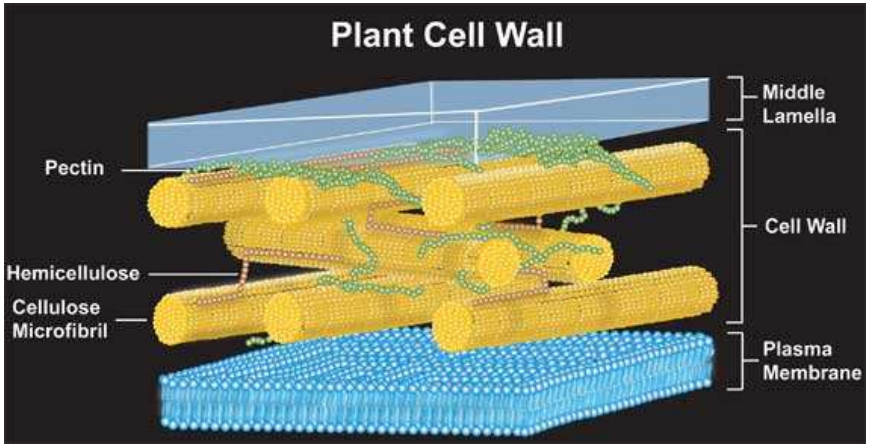
Adapted from Qiagen

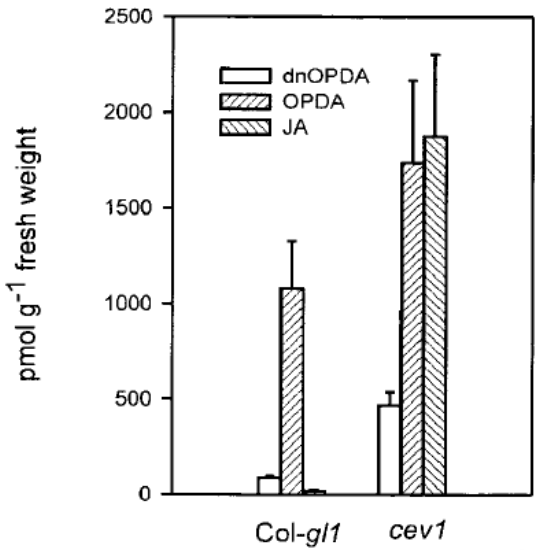
JA biosynthesis (2)

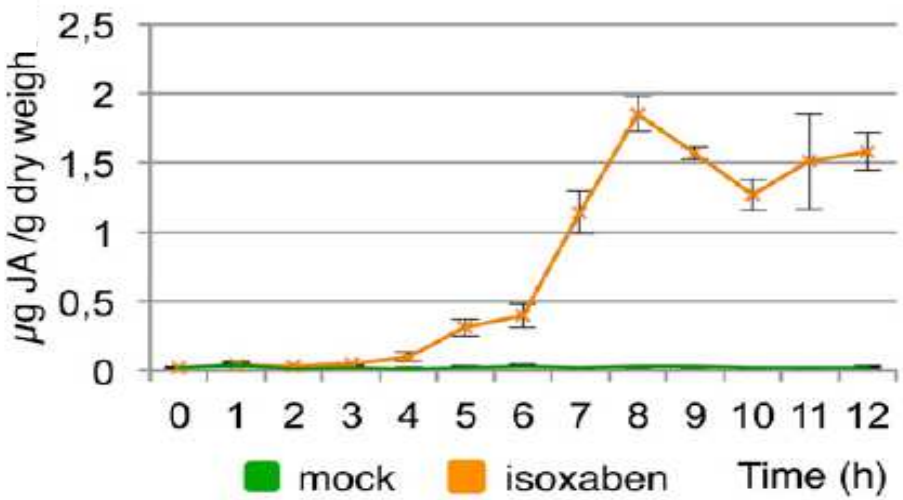


Adapted from Qiagen

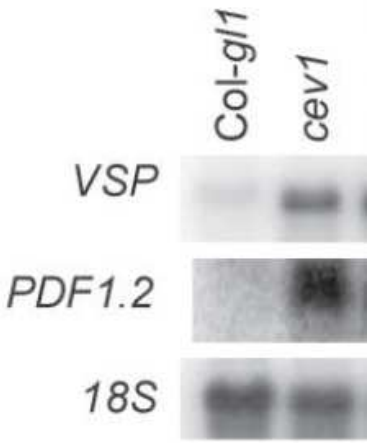
Plants with altered cellulose deposition accumulates jasmonic







Denness *et al.,* 2011, Plant physiology



Ellis *et al.,* (2002) Plant Cell

Summary

Following a wound or a change in cell wall composition:

- The plant rapidly produces jasmonates (JA, MeJA, JA-Ile, Jasmone, etc…)
- The stress signal spreads rapidly throughout the plant at a velocity (leaf to leaf) of 5 cm/min.

Summary

The JAZ-VENUS:

- Is a jasmonate sensor
- Allows to estimate the velocity of wound responsive signal(s)
- Allows to follow the dynamics of JA responses to isoxaben treatments

Conclusions

- The auxin (DII-VENUS) and jasmonate (JAZ-VENUS) sensors complement transcriptional reporters by reporting the input in the pathway (Vernoux *et al.,* (2011) *Mol Syst Biol*)

- Using modelling the non linearity between the observed fluorescence and the actual hormone distribution can be determined

But…

It is just a step towards a quantitative biology.

New *truly quantitative* sensors?

Acknowledgements

JAZ-VENUS:
Antony Champion (Dakar)
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Alistair Middleton (Nottingham & Heidelberg)
Darren Wells (Nottingham)
Malcolm Bennett (Nottingham)
Teva Vernoux (Lyon)

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Christine Granier

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