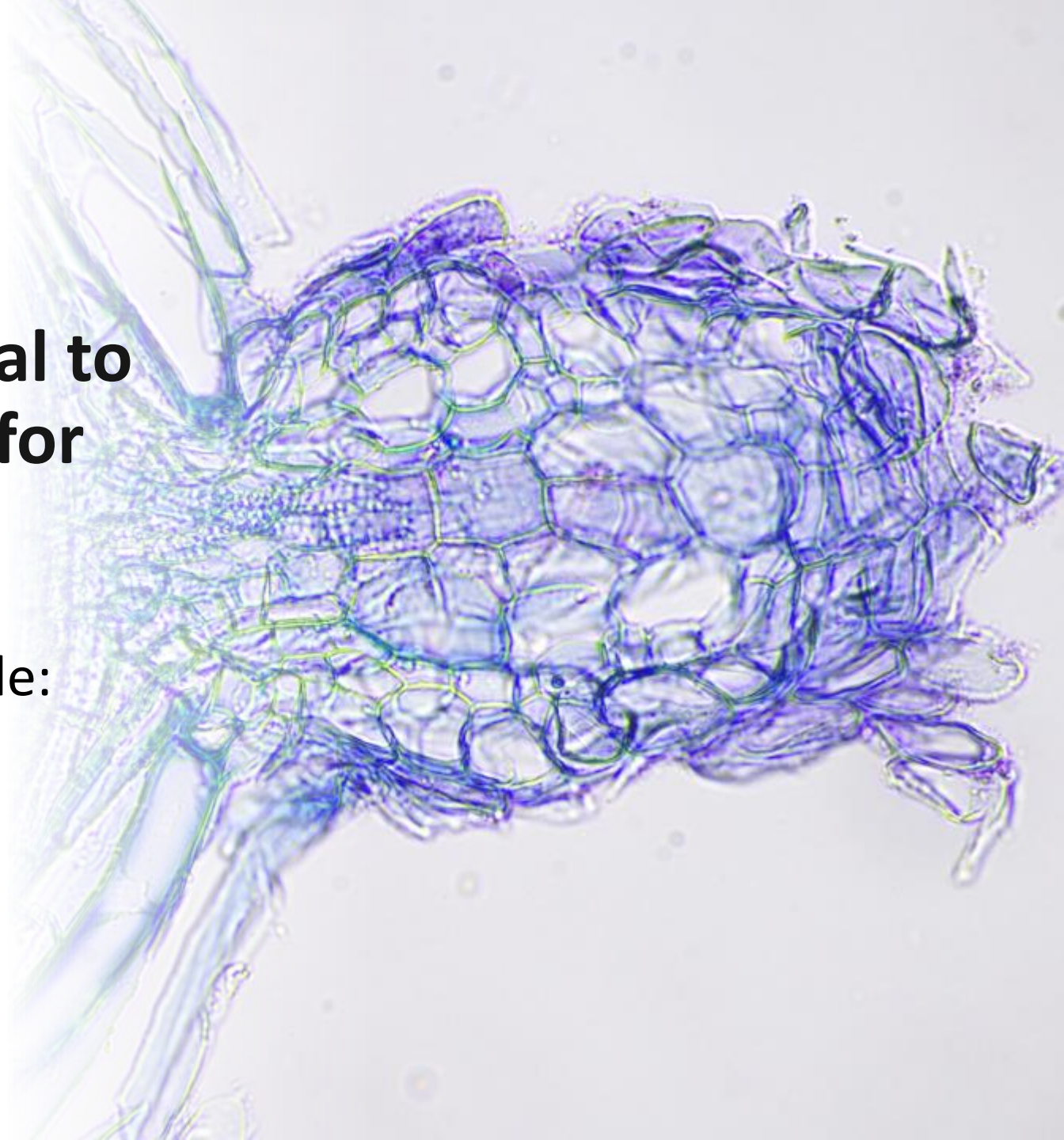
UNIVERSITY OF CAMBRIDGE

CROP SCIENCE CENTRE

Can we switch from chemical to biological nitrogen fixation for sustainable food security?

From lateral root to functional nodule: engineering organogenesis in barley



Min-Yao Jhu

2023 Cambridge Global Food Security Symposium

Oldroyd Group

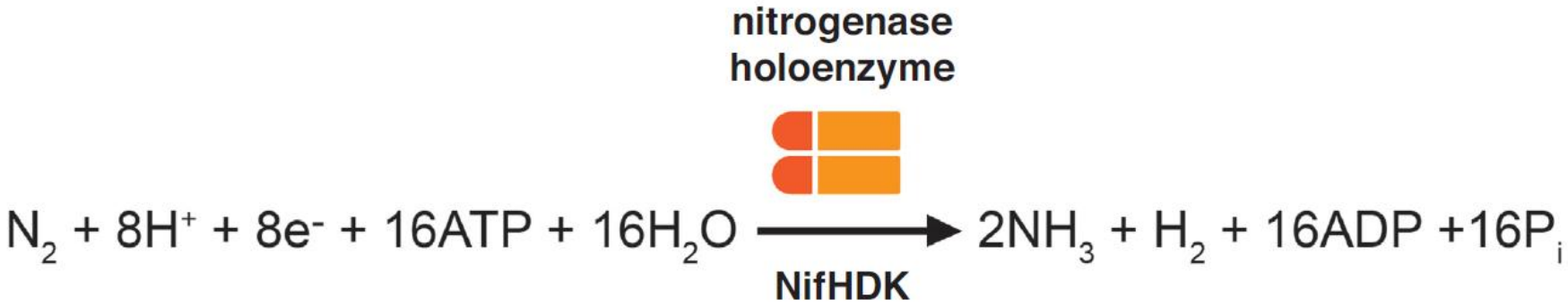
The Vision of ENSA
Engineering Nitrogen Symbiosis for Africa

To Sustainably Increase Yields for Small-holder Farmers

- Through a detailed understanding of how plants associate with **beneficial microorganisms**, we aim to broaden their use in agriculture to facilitate sustainable productivity.
- Crop plant productivity is highly dependent on the availability of a **nitrogen source** and farmers generally provide this as **fertilizers**.

Biological nitrogen fixation

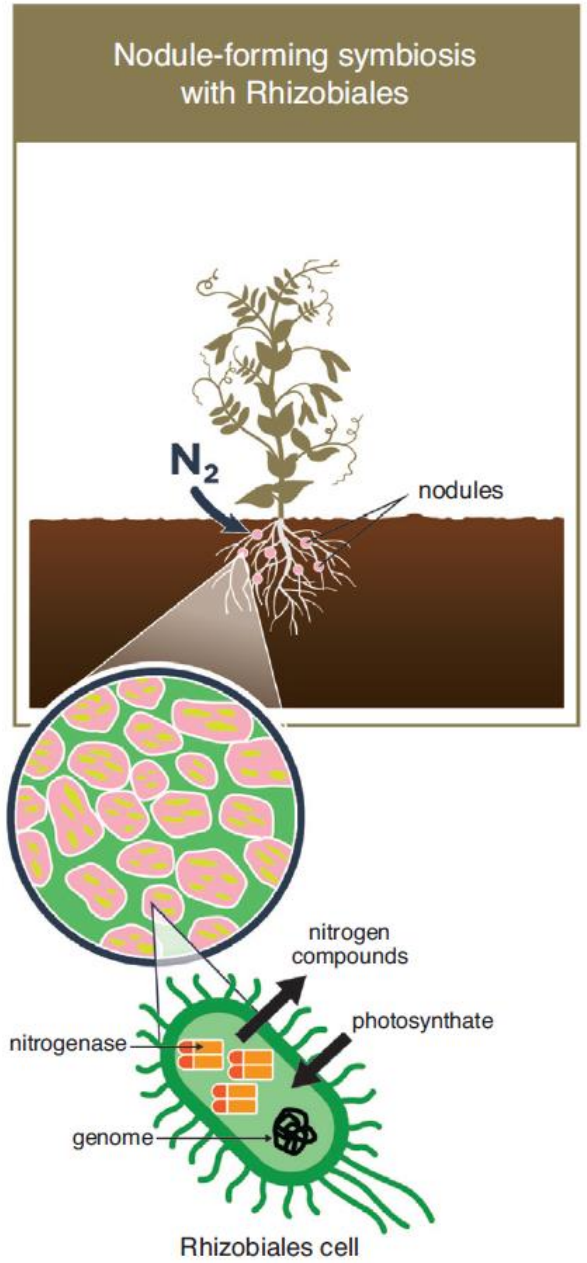
(a)



- **Nitrogen-fixing bacteria**
- **Nitrogenase**: convert di-nitrogen to ammonia, a reactive form of nitrogen then can be used in biological processes.
- Legumes form specialized organs on the roots, called **nodules**, that **house the nitrogen-fixing bacteria and provide the suitable oxygen-regulated environment for nitrogen fixation to occur.**

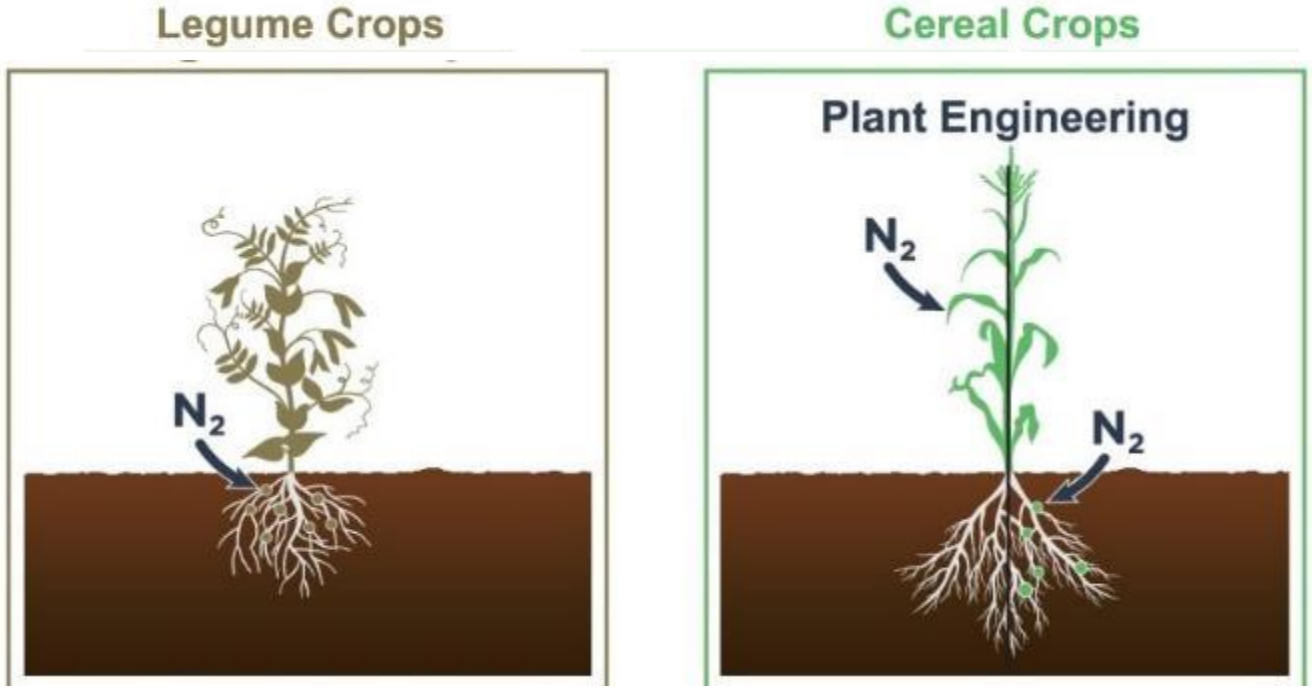
(b) Legume Crops

Bloch et al., 2020

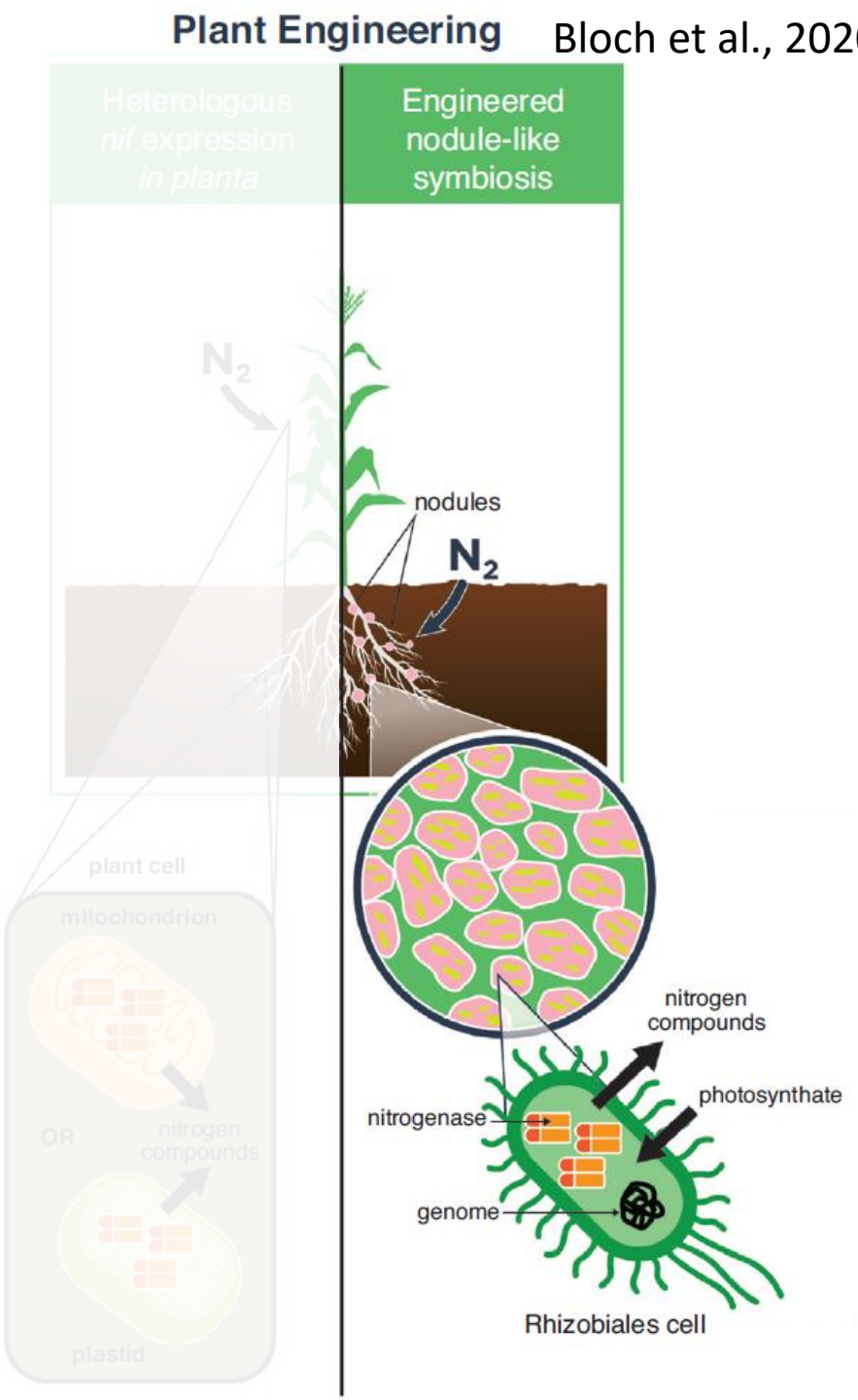


Engineering a Solution

- ENSA: we are attempting to transfer **the capability of associating with nitrogen-fixing bacteria** from legumes to **cereals**.
- **Self-fertilizing cereals**: can support their own productivity without the need to use nitrogenous fertilizers.



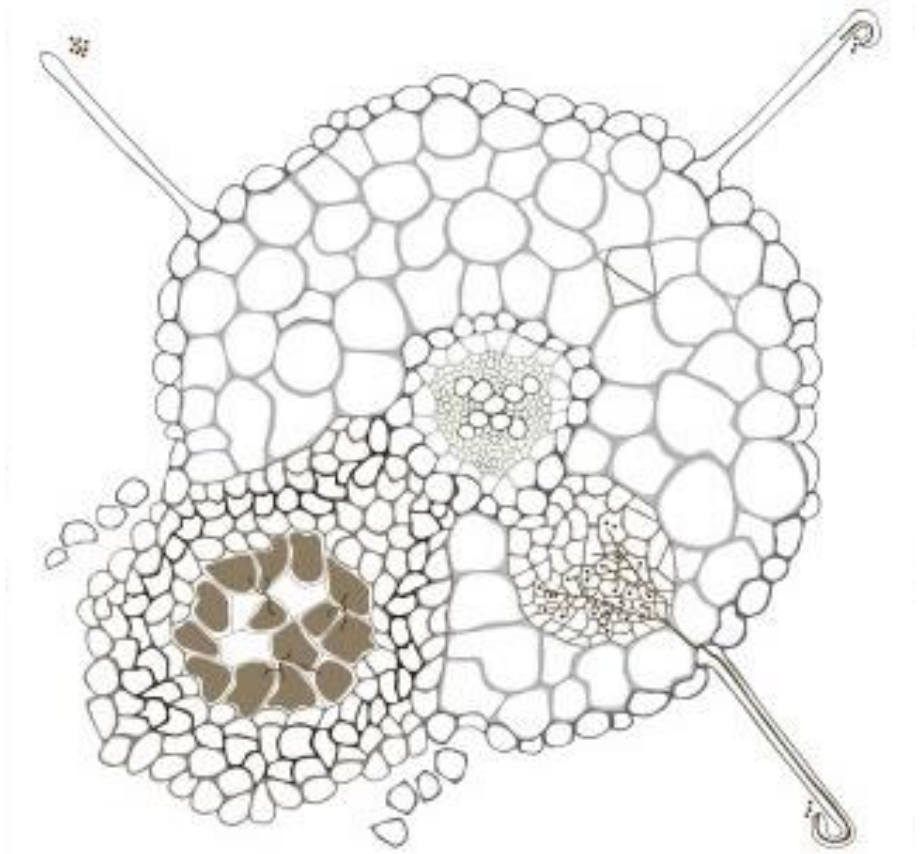
Bloch et al., 2020



The Four Components to Engineering Symbiosis

1. **Pre-infection**: Engineer Perception of Nitrogen Fixing Bacteria

2. **Nodule initiation**: Engineer Bacterial Infection Process

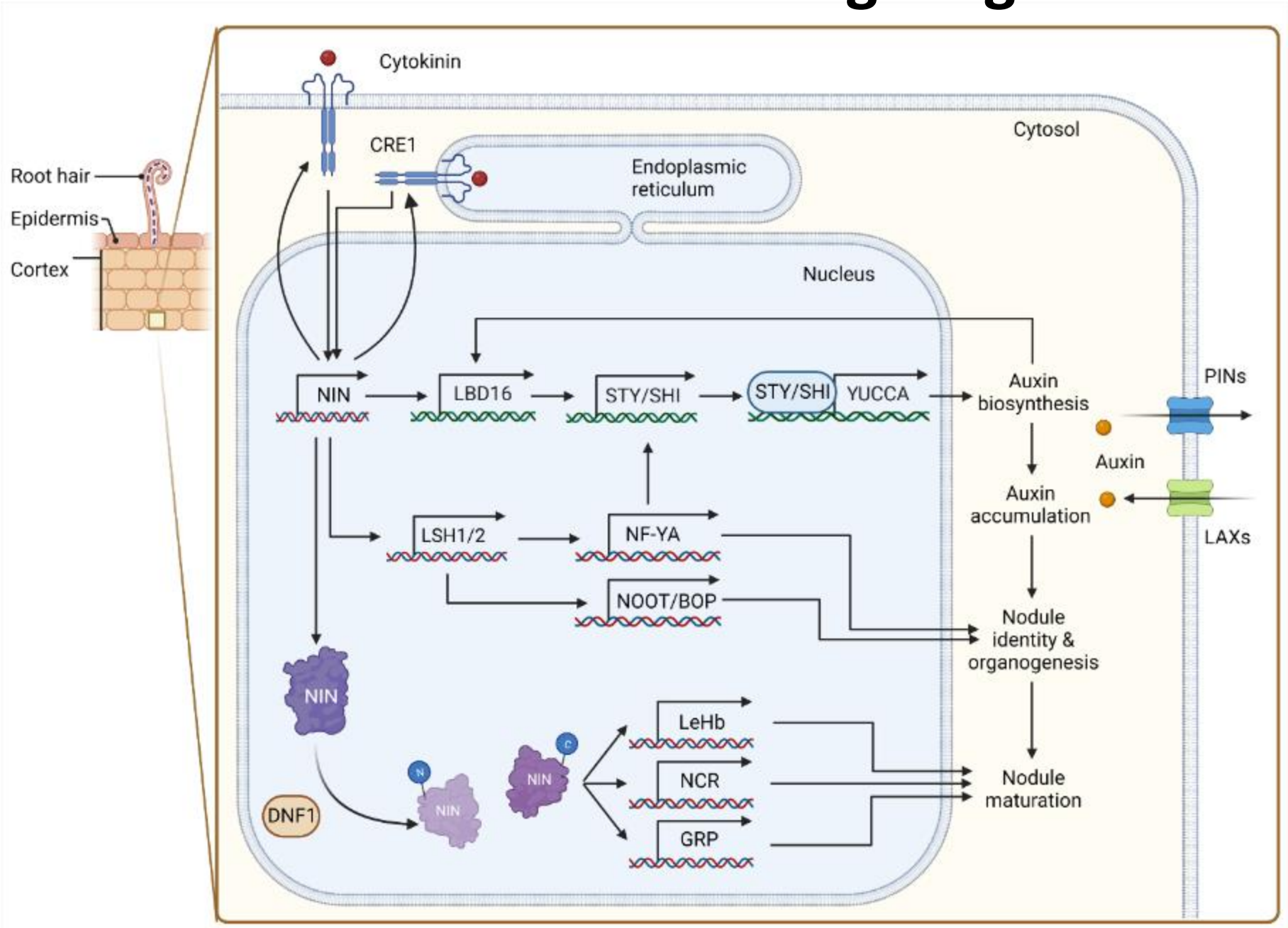


4. **Mature nodule**: Engineer the Appropriate Environment for Nitrogen-Fixation within the Nodule

3. **Nodule primordia**: Engineer Nodule Organogenesis

Lin et al., 2020

Mechanisms of nodule organogenesis

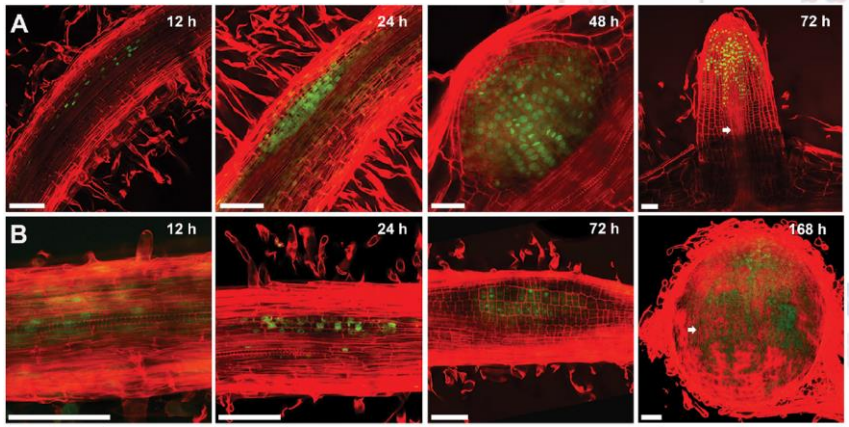


Jhu & Oldroyd, 2023, *PLOS Biology*

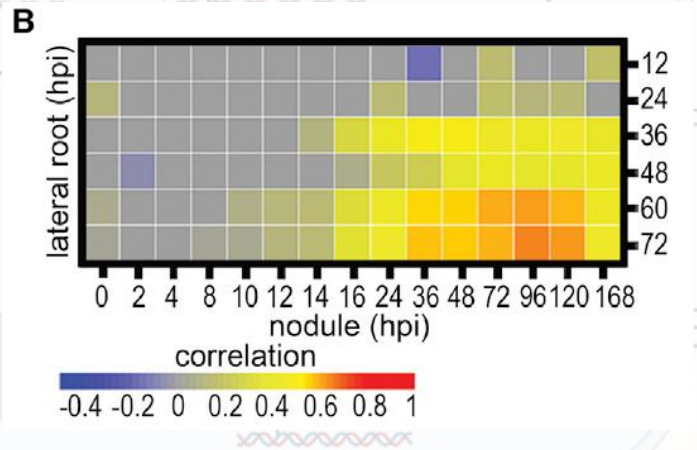
Mechanisms of nodule organogenesis

Katharina Schiessl

Shared genes drive lateral root development and root nodule organogenesis

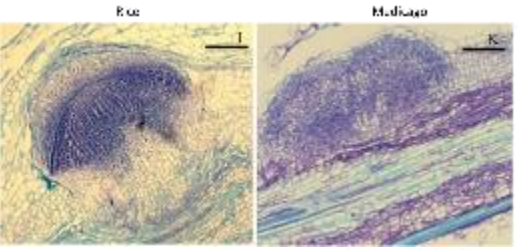


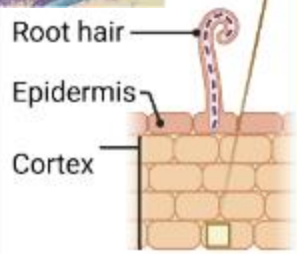
Soyano et al., 2019, *Science*; Schiessl et al., 2019, *Current Biology*



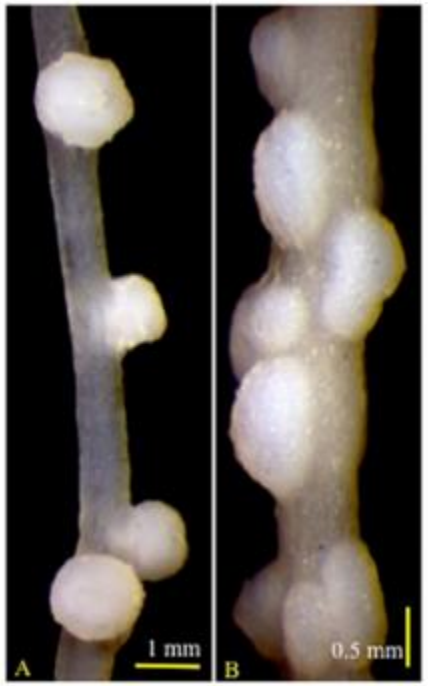
Jhu & Oldroyd, 2023, *PLOS Biology*

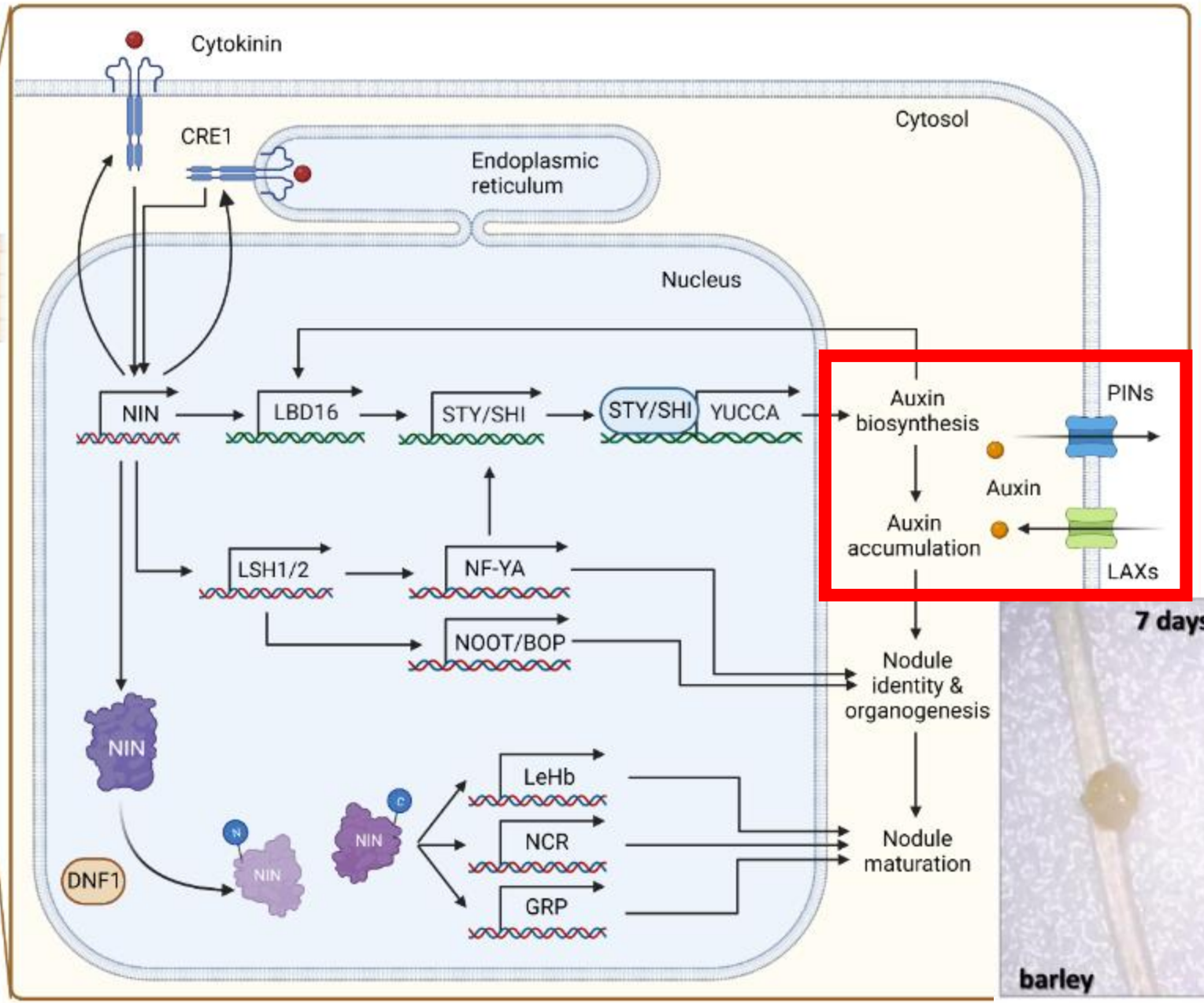
Mechanisms of nodule organogenesis





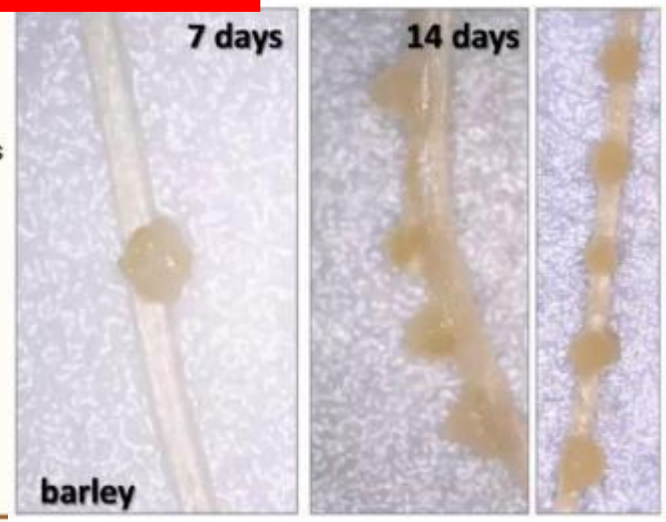
Hiltenbrand et al., 2016





Auxin-Induced Nodule-Like Structures

Mandana Miri



Mechanisms of nodule organogenesis

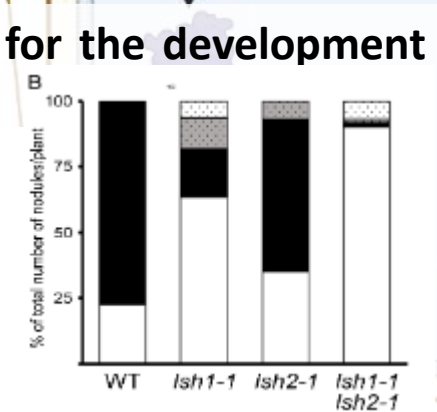
Katharina Schiessl

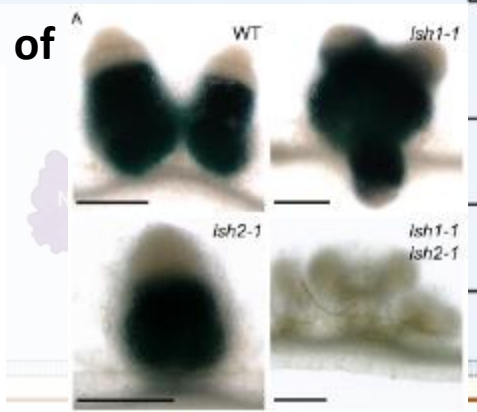
Schiessl et al., 2023, bioRxiv

Light sensitive short hypocotyl (LSH)

***LSH1* and *LSH2* are required for the development of nitrogen fixing nodules.**

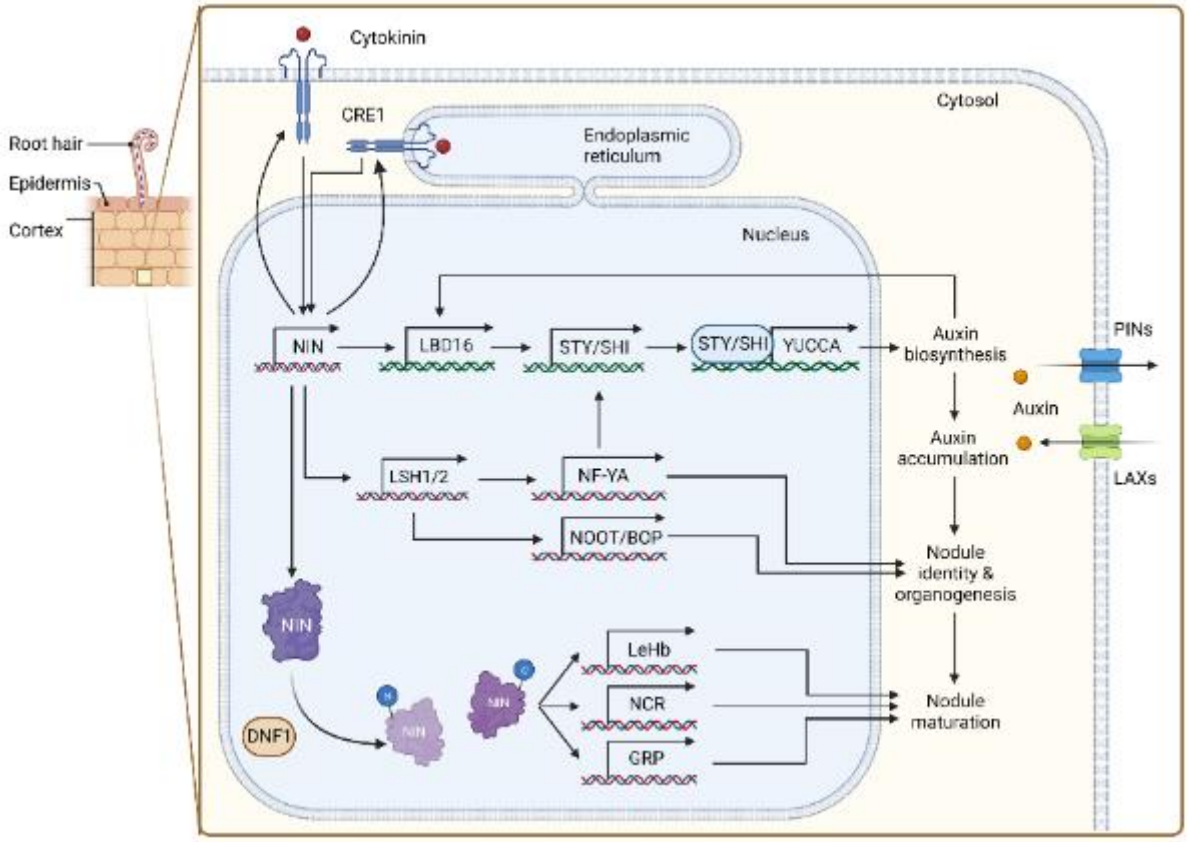
- white nodules
- blue, *pnifH*:GUS expressing nodules
- white multilobed/fused nodules
- blue, *pnifH:GUS* expressing multilobed/fused nodules

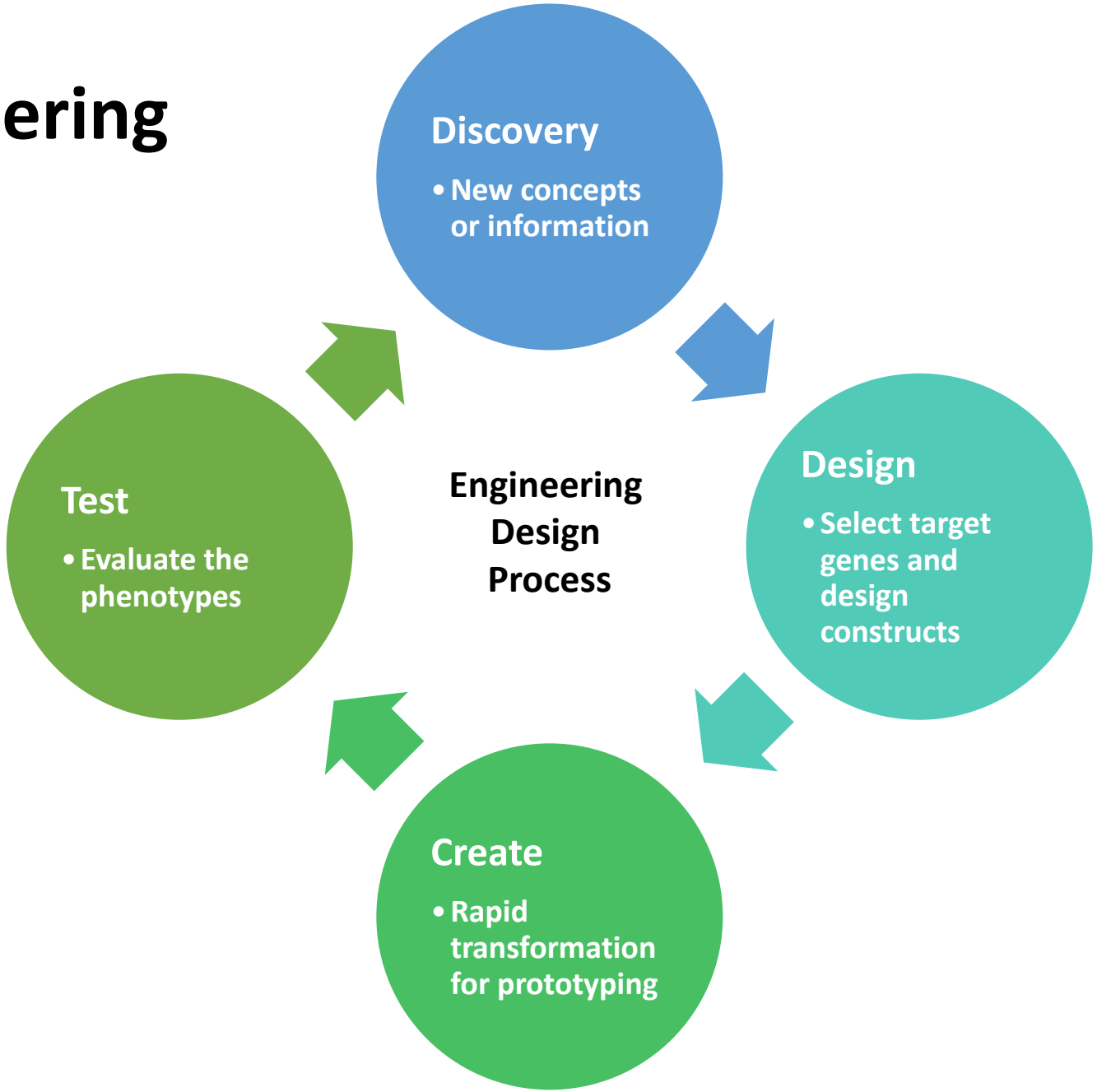




Jhu & Oldroyd, 2023, *PLOS Biology*

From Discovery to Engineering





From Discovery to Engineering

Engineering Design Process

Discovery
- New concepts or information

Design
- Select target genes and design constructs

Create
- Rapid transformation for prototyping

Test
- Evaluate the phenotypes

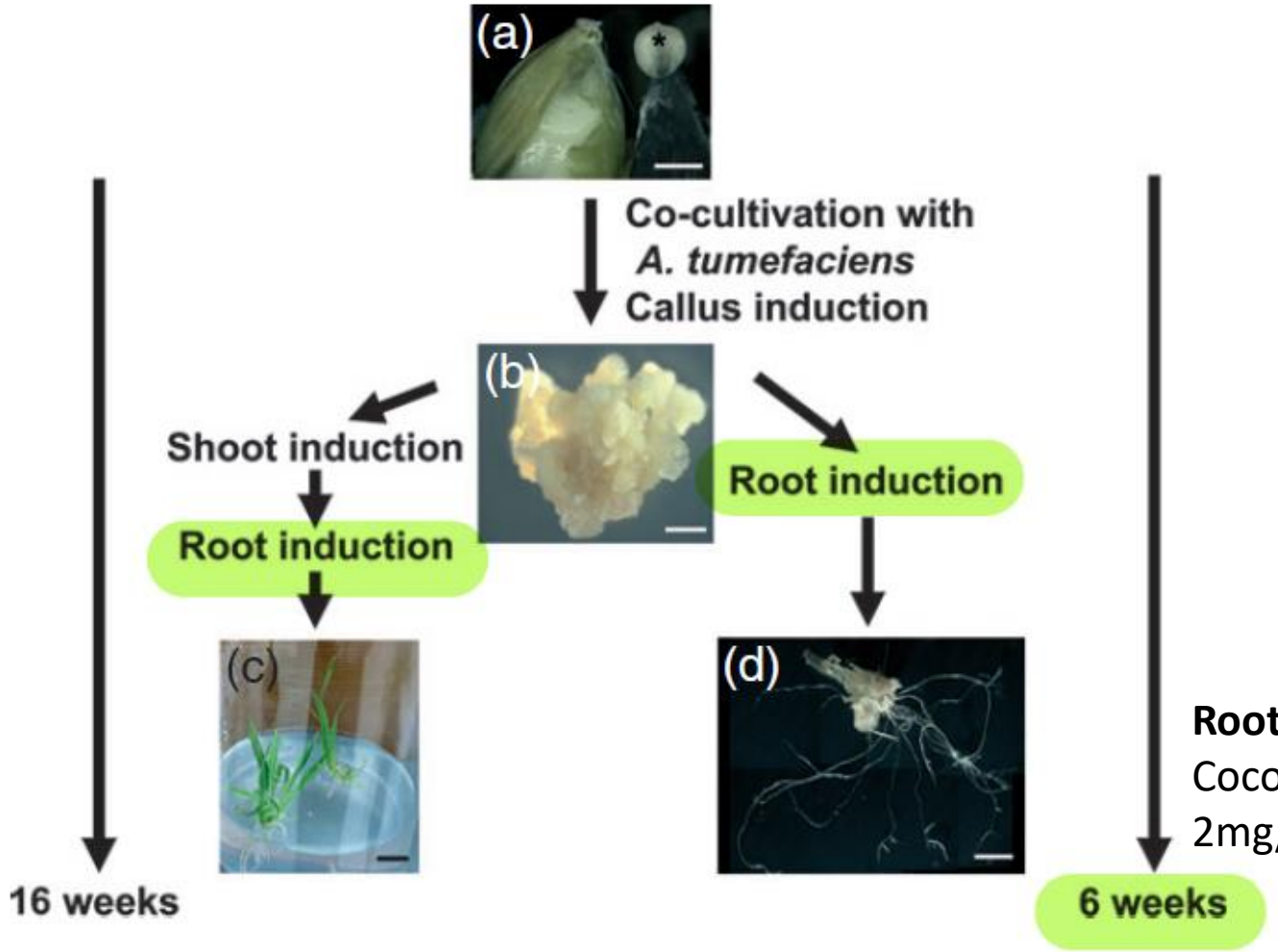
Product development
- Stable transgenic plants

STARTS – A stable root transformation system for rapid functional analyses in barley

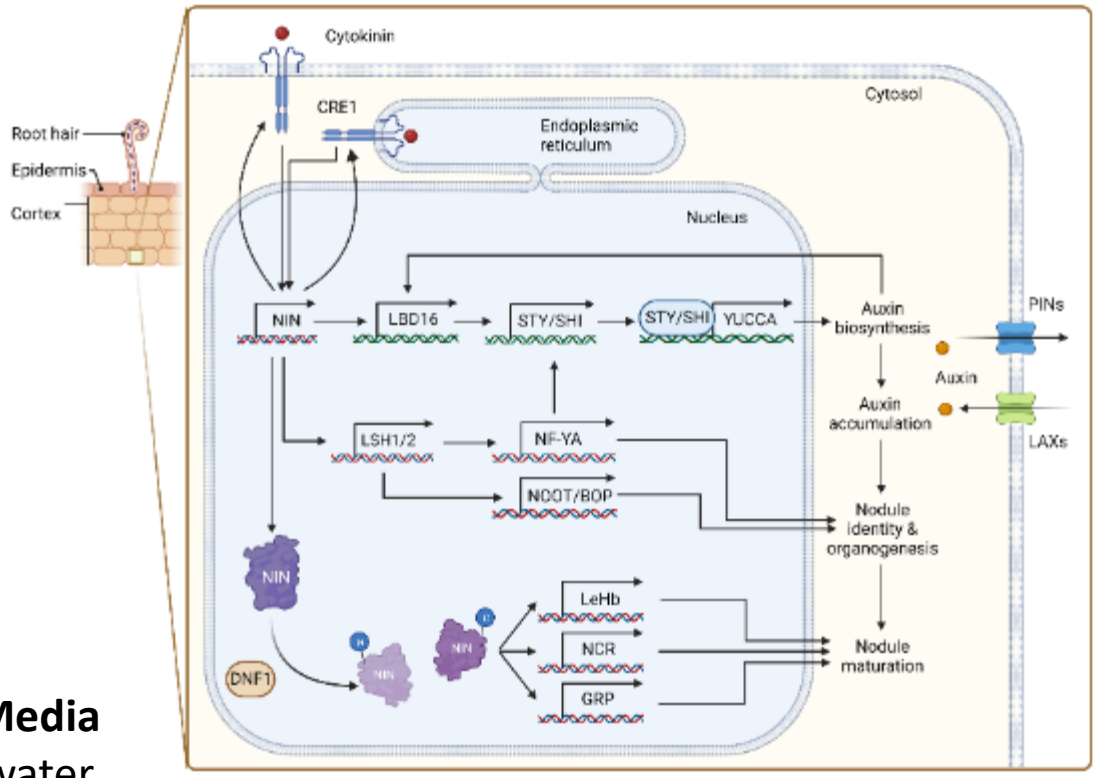
Create

- **Rapid transformation for prototyping**

Imani et al., 2011



Rooting Media
Coconut water
2mg/l IBA



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