

# The Fungi Plants Depend On

## Orchids, Endophytes and Microbiomes



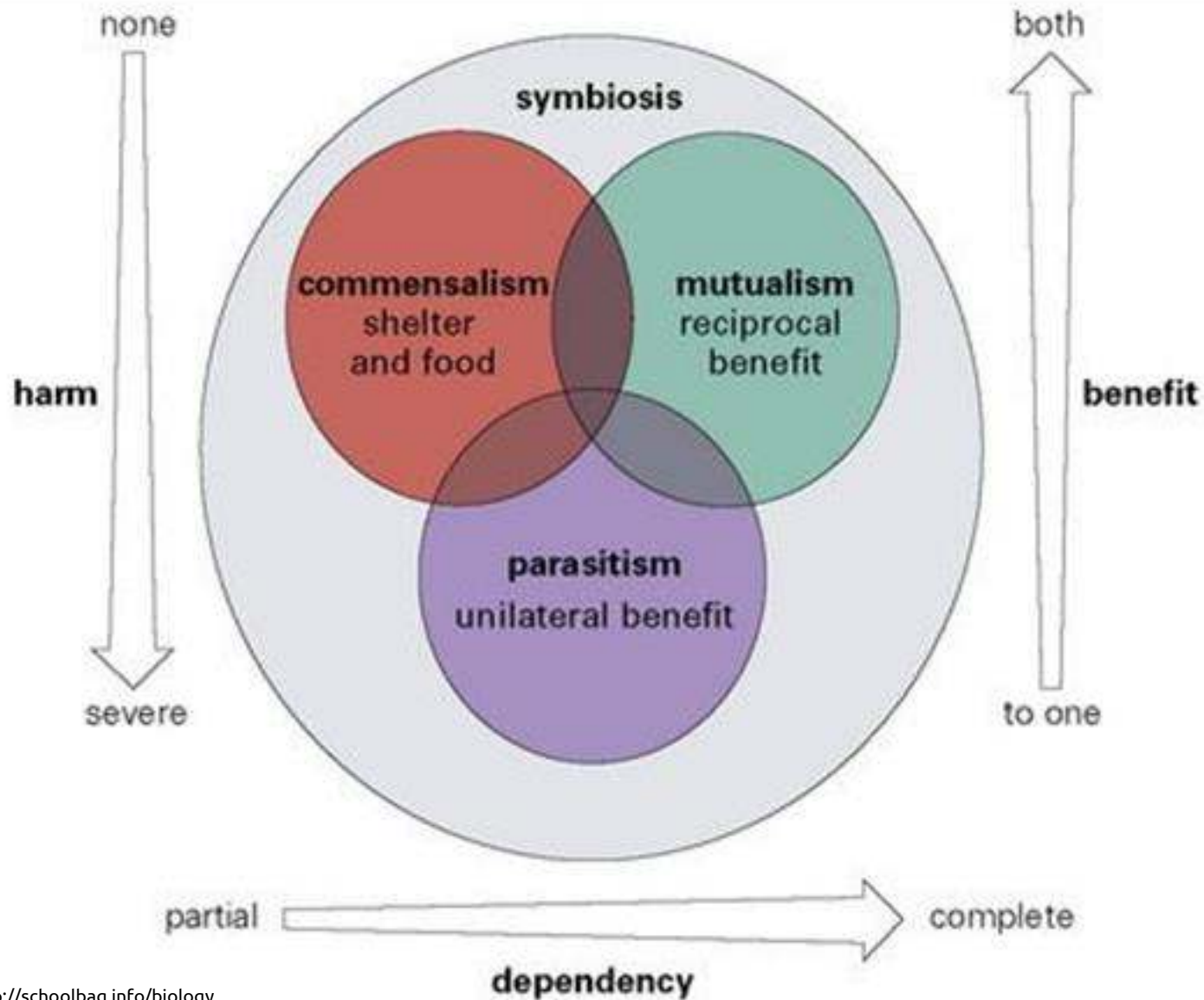
# Everything is **Smothered** in Microbes



**All large organisms** host a diverse community of micro-organisms (*fungi, bacteria, archaea, protists, viruses*) – “**microbiome**”

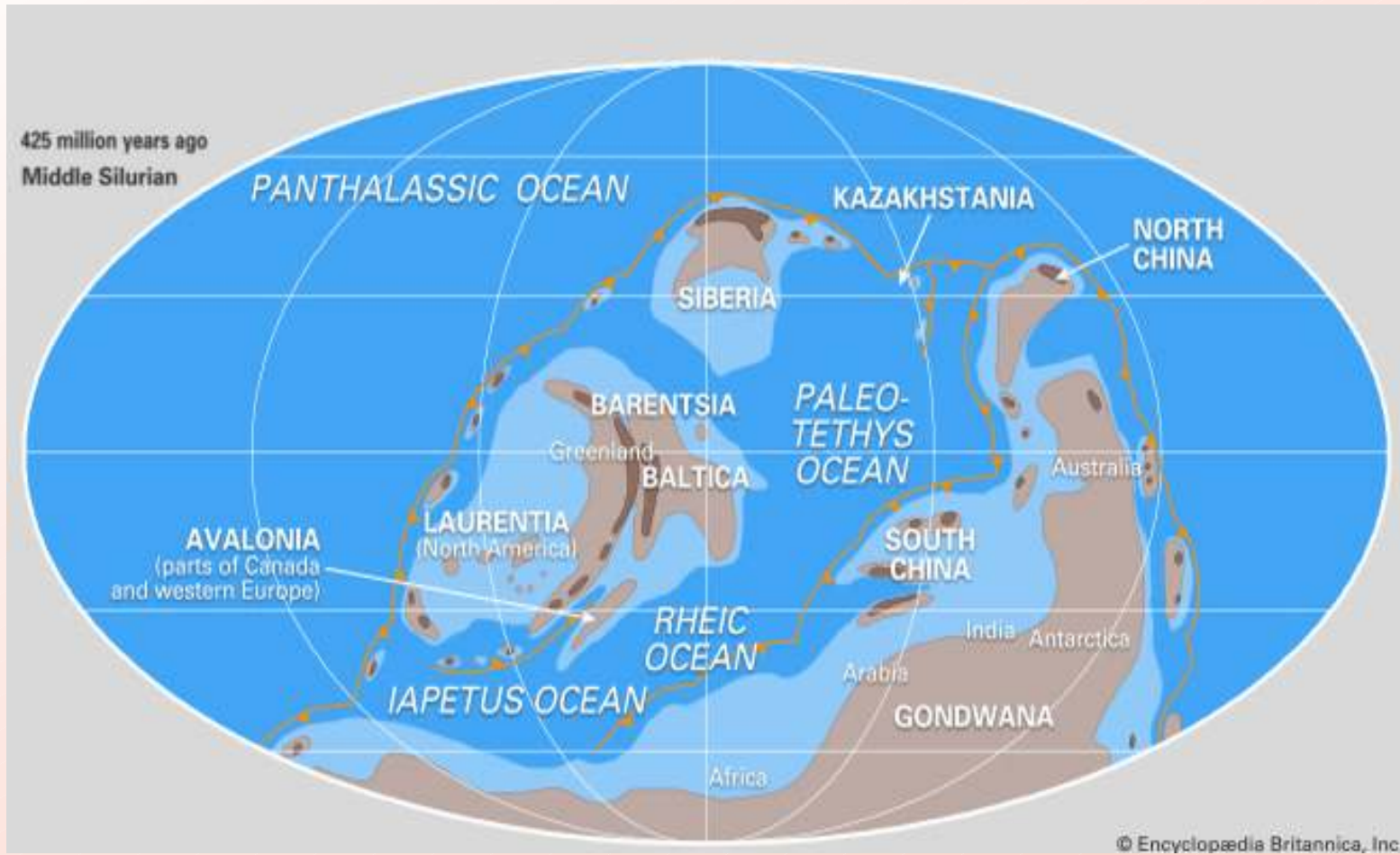
Many ecosystems **dominated by microbes** in terms of biomass<sup>1</sup>

What are the **demographics of microbial communities?**

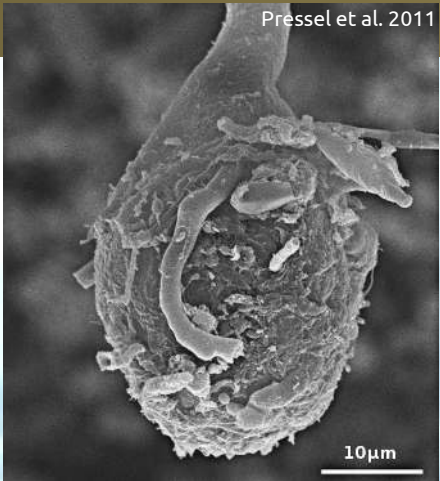


## Mutualism-Parasitism Continuum

# Plants Colonised the Land Thanks to Fungi



- Continents colonised by streptophyte **algae** 470 – 450 MYA<sup>1</sup>
- Made possible by **mycorrhizal fungi**: inorganic nutrient access



# An **Avalanche** of Fungal Endophytes

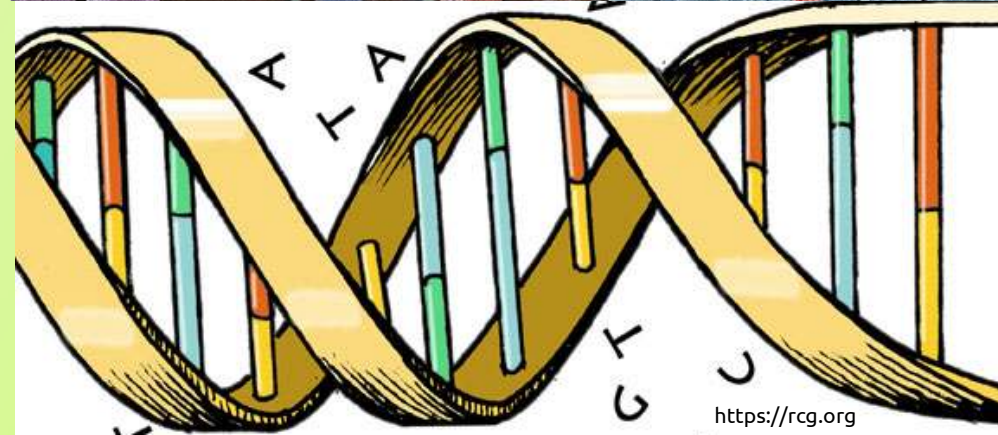
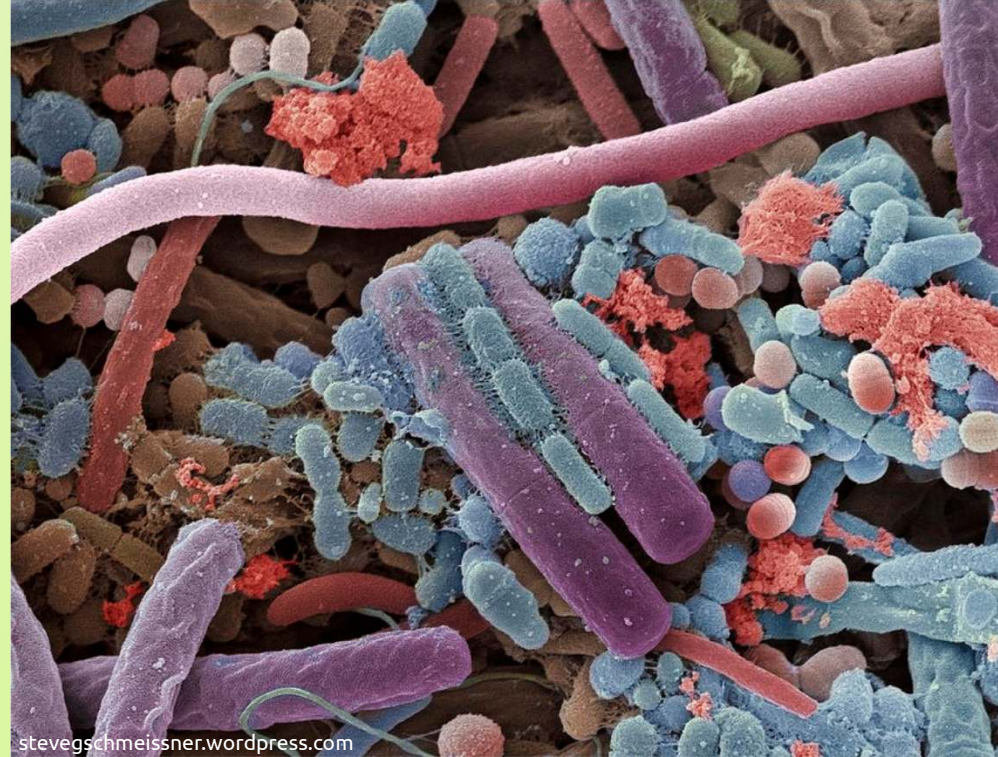
- *Ἔνδον*, *endon* (**inside**), *φυτόν*, *phutón* (**plant**) – stems, leaves, roots, flowers, fruit, seeds
- Endophytic fungi **found whenever they have been sought** – tropics to poles<sup>1</sup>
- Over **250 spp. of fungi** cultured from leaves of a single tree sp.<sup>2</sup>



# The Uncultured Masses

- Most micro-organisms **not culturable using** <sup>1,2</sup>
- *Described fungi: 140,000 spp.*
- *Est. total diversity: 2-3 million spp.*<sup>3</sup>

... So how can we study the **unculturable ones?**



<sup>1</sup> Hugenholtz, Goebel & Pace 1998, <sup>2</sup> Rappe & Giovannoni 2003,

<sup>3</sup> Hawksworth & Lücking 2017



<http://utbfc.utk.edu>



<http://www.forestryimages.org>

UGA2252020b

# What's in it for the **plants**?

- 1970s – tall fescue & ryegrass → **toxicosis in grazing cattle**<sup>1</sup>
- Mycotoxins produced by *Phialocephala* **slow growth rate** of spruce budworm<sup>2</sup>
- Ammonia scavenging by fungi **detoxifies plant cells**<sup>3</sup>

<sup>1</sup> Bacon et al 1977, <sup>2</sup> Carroll 1986, <sup>3</sup> Saraf et al. 2014

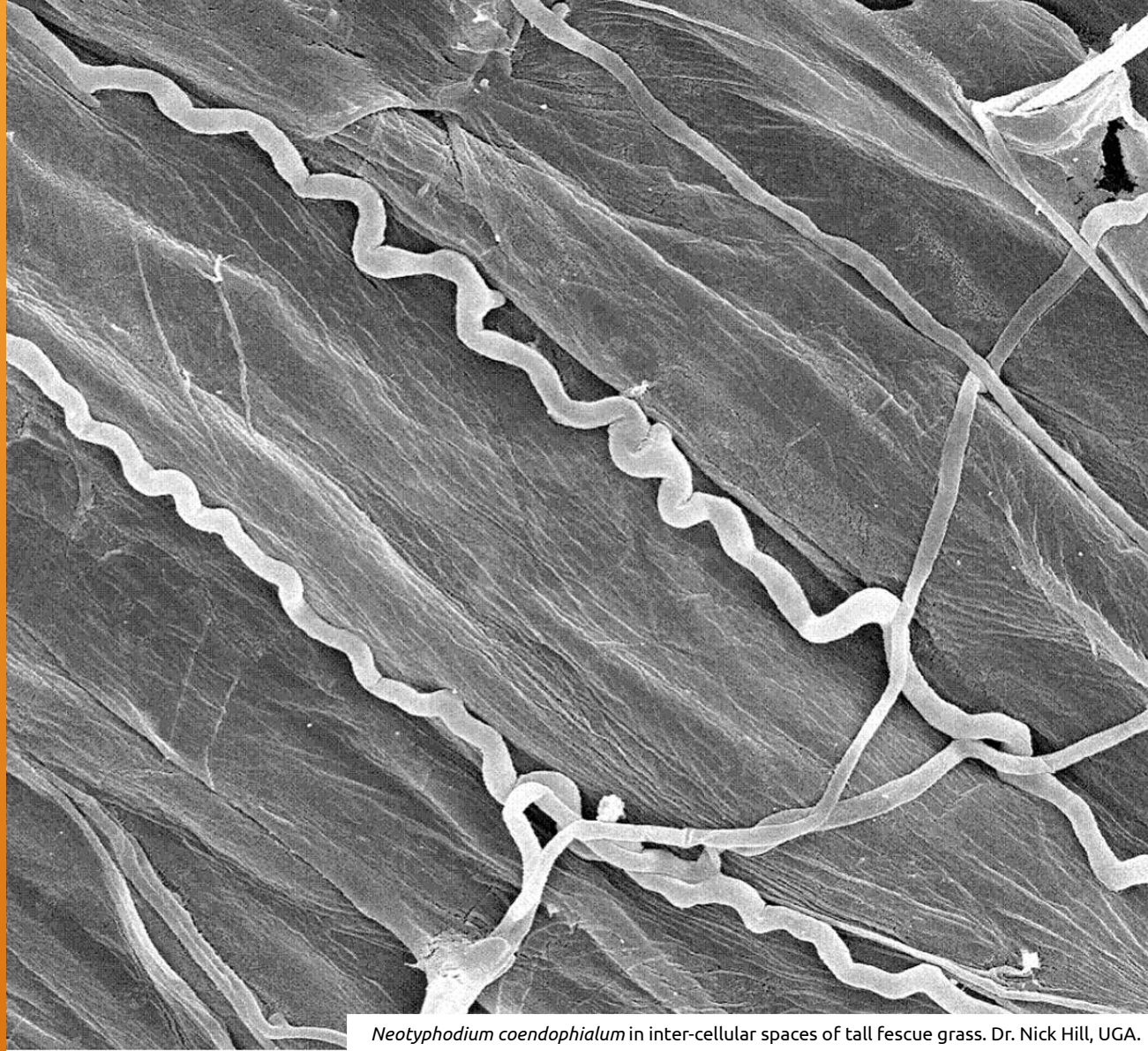
# Drought Protection



**Reduced drought stress<sup>1</sup>: expanded natural range?**

# What's in it for the **fungi**?

- **Protected niche**
- **Nutrients**
  - **Sugars** e.g. raffinose<sup>1</sup>
  - Nitrogen from **ammonia & ethylene scavenging**
- Can be **disease-causing**; switch to pathogenesis if plant stressed/weakened



*Neotyphodium coendophialum* in inter-cellular spaces of tall fescue grass. Dr. Nick Hill, UGA.

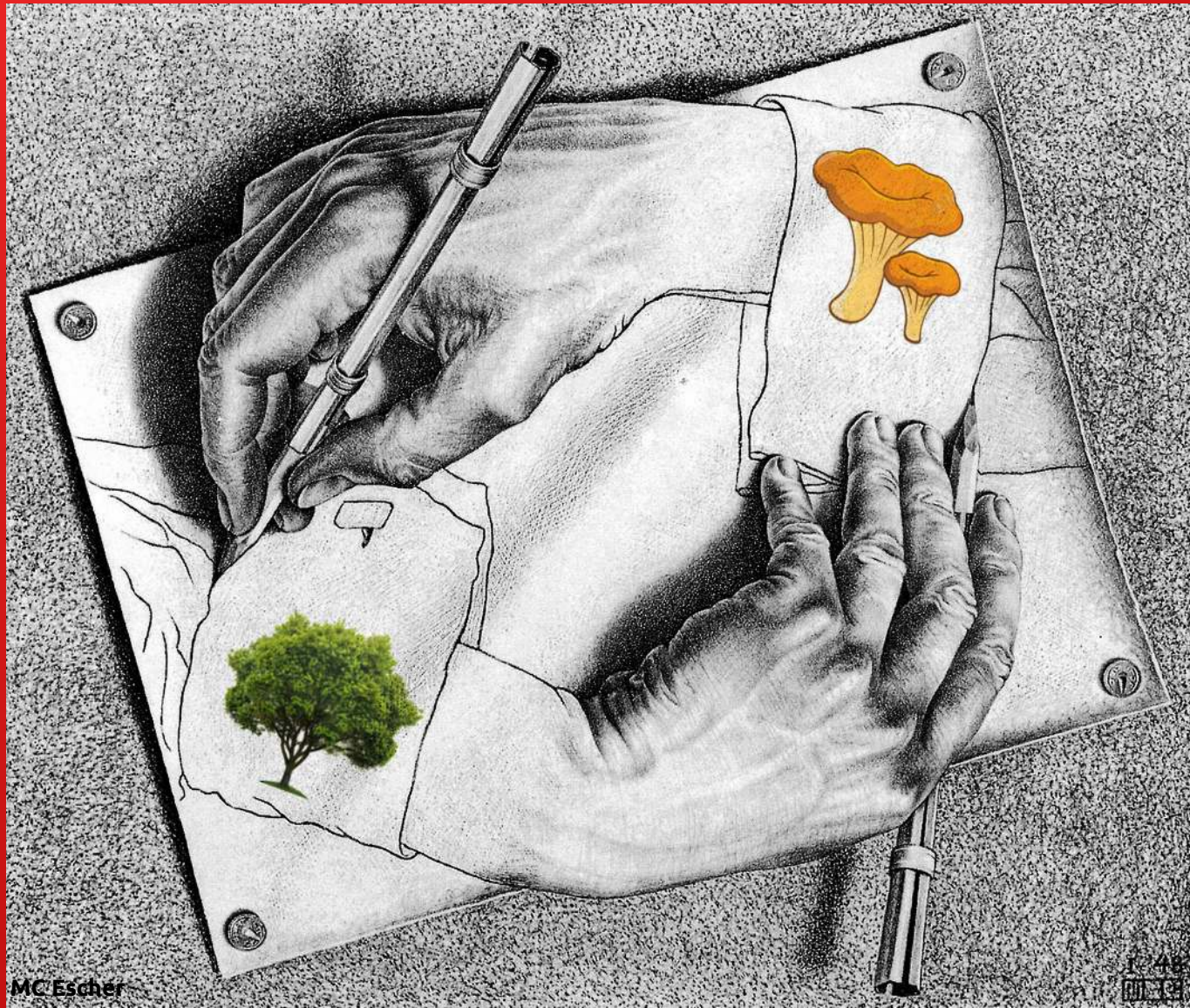
<sup>1</sup> Behie & Bidochka 2014

# Foraging Ascomycete Hypothesis

- Some fungi maintain an endophytic life stage to **enhance dispersal**
- Bridge gaps in substrate in **space and time**<sup>1</sup>
- **Dormancy until leaf senescence:** outcompete forest-floor fungi



Figure 1. Visualization of the Foraging Ascomycete hypothesis, also known as "viaphytism". Leaves are infected endophytically by spores, then act as dispersal vectors of fungi to new substrates.



# The Orchidaceae

- **28,000 orchid spp., largest family of flowering plants** (4x no. of mammal spp.)<sup>1</sup>
- All orchids highly dependent on **orchid mycorrhizal fungi (OMF)**



<sup>1</sup> Ercole et al. 2013

# Intracellular Intimacy

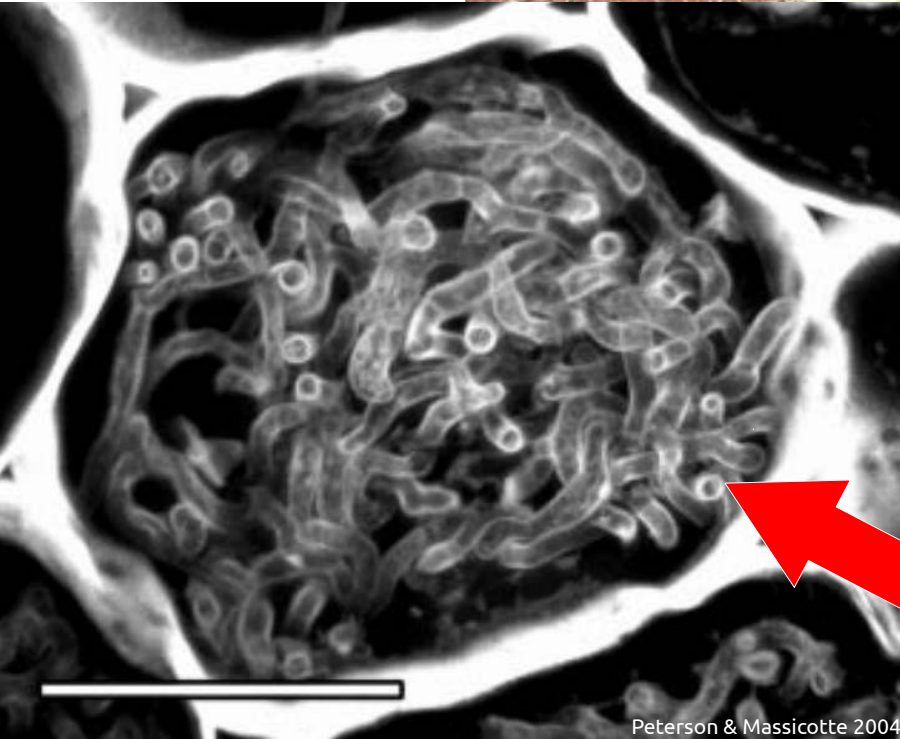


peanut



orchid

- **Seeds lack carbon reserves:** fungus required for germination
- **Ammonium** from orchid seedling, **sugars** from adult plant<sup>1</sup>
- **Pelotons** sites of nutrient exchange



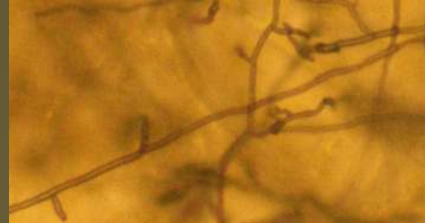
# 'Cheating' Orchids

- No carbon from  $\text{CO}_2$ 
  - all from fungus partner:  
*myco-heterotrophy*
- Photosynthetic machinery **discarded** – gene mutations
- “Cheating” – shift to **parasitism**



# Underground Ecology

- Western underground orchid (*Rhizanthella gardnerii*)
- *Thanatephorus*/*Ceratobasidium* spp.<sup>1</sup>
- Yilbarra (*Melaleuca uncinata*)



<https://janinemackintosh>



<https://orchid.unibas.ch>



<https://en.wikipedia.org>

<sup>1</sup> Bougoure et al. 2009

# Do Fungi **Evolve** with their Orchid Hosts?

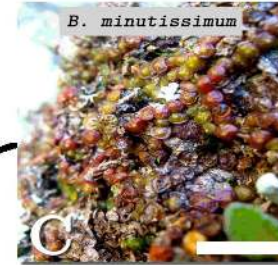
- *Bulbophyllum*: largest orchid genus

- Only prior fungal study on **Réunion Island**

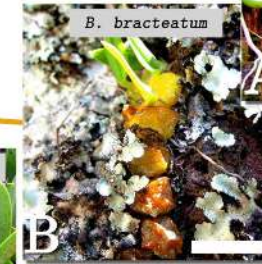




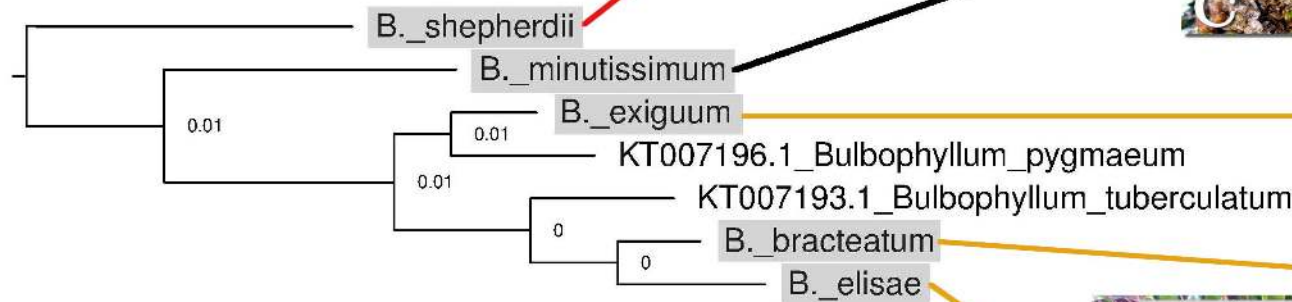
**Ceratobasidium**

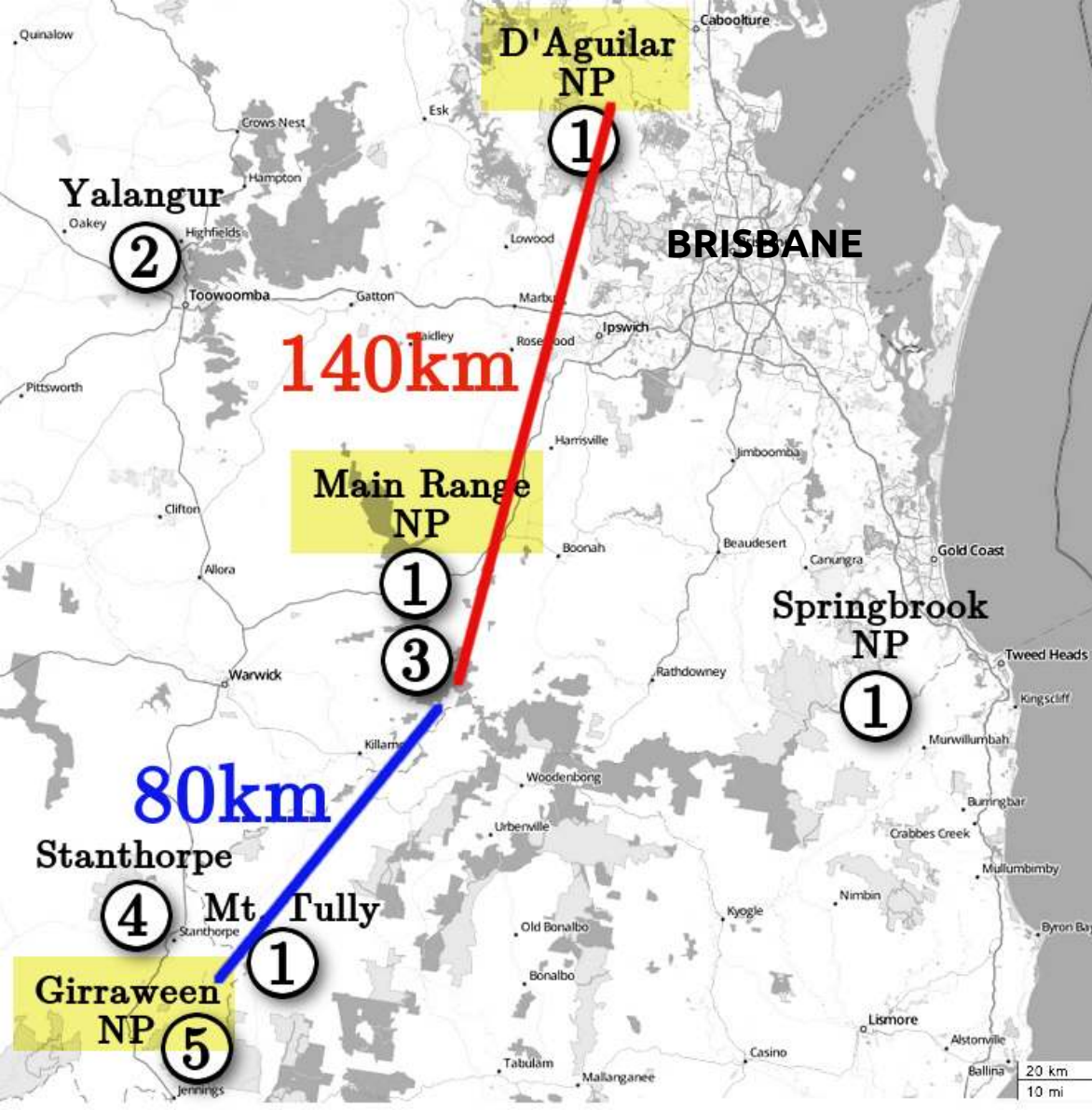


**Non-OMF  
endophytes/  
pathogens**



**Tulasnella**  
**Serendipita**  
**Dark septate  
endophytes**





# Long Distances, High Specificity

- 220 km same *Tulasnella* sp. fungus over 3 orchid spp. natural range

# How do Endophytes Respond to **Seasonal Water Stress?**

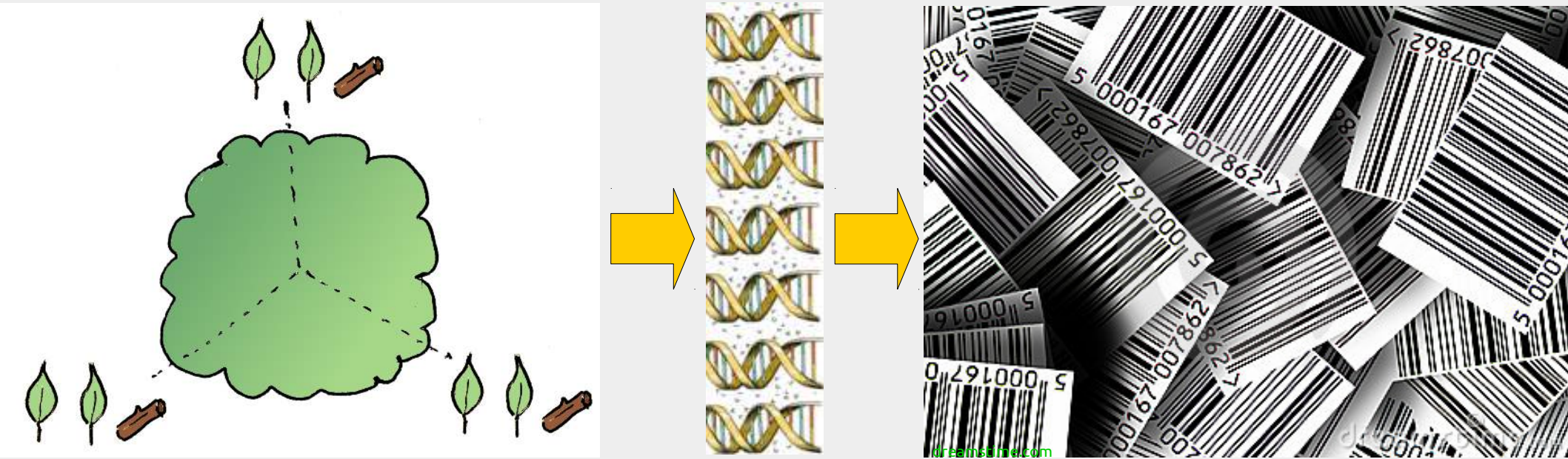
- **Cape York monsoon** – extreme rain fluctuation
- Native rainforest plants (& fungi) **highly adapted**

Could **Entire Endophyte Communities**  
Evolve with their Hosts?

- Look at **major plant lineages** in same ecosystem



# How Can We Study **Whole Communities**?



- Sequencing of one DNA region in **every fungal cell** – millions of endophytes
  - **Snapshot** of community composition
    - *Single feather from every bird on Straddie*

# Wet Season Leaf Endophytes



*Dimorphocalyx  
australiensis*

Axis 2 (10.14 %)

*Cupaniopsis  
flagelliformis*

**Bryophytes**



Axis 1 (15.13 %)

Bryophyte 1

Axis 3 (8.839 %)

**261-362** endophyte  
spp. per plant

Small dataset

Which fungal lineages proliferate during the **dry monsoon period** (May-Nov)?

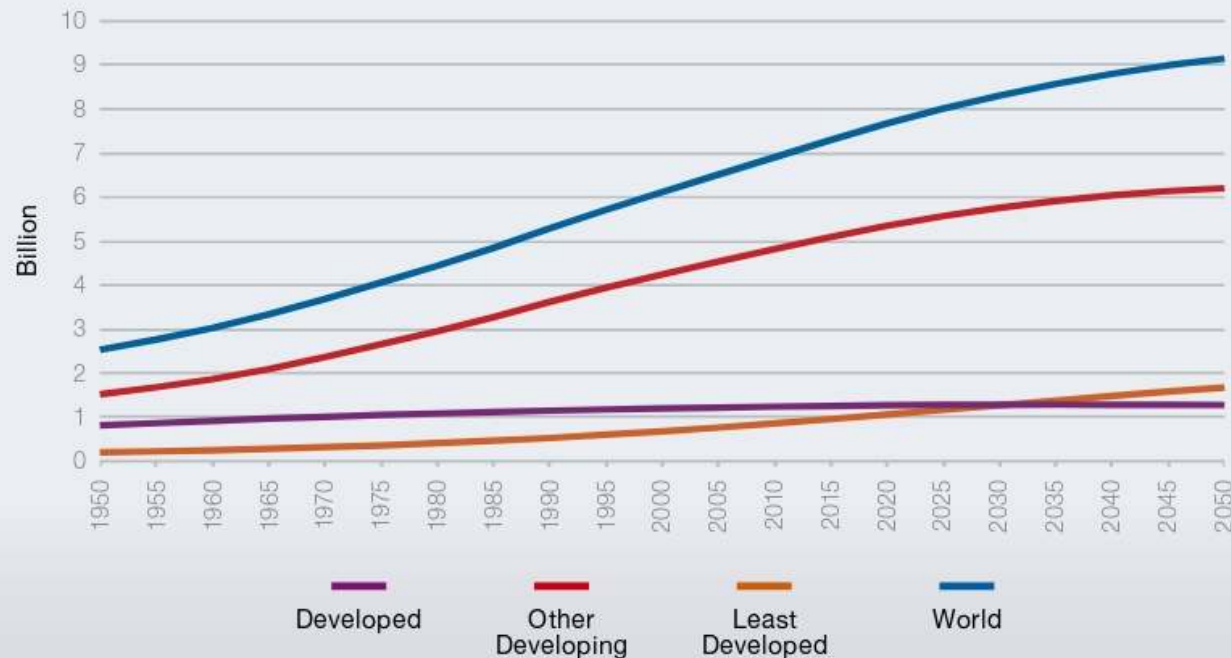
Are **drought-associated changes** in community composition similar across all plant hosts?



# But Why Study Endophytes?

- **Global demand for food** likely to rise **70% by 2050<sup>1</sup>** – climate change posing new challenges to agriculture
- **Heavy inputs** (fertilisers, herbicides, pesticides) – **current ecological crisis**

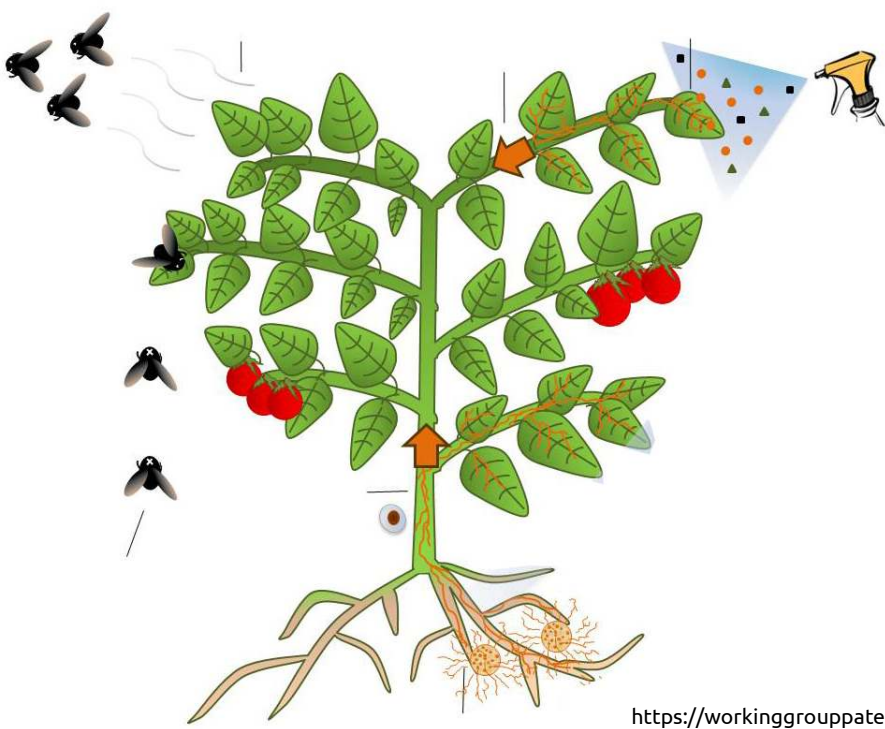
Population growth



Source: UN Population Division, from van der Mensbrugghe et al. 2009

# Alternative Path Needed for Agriculture

- Integrate beneficial plant microbiomes: **plant growth, nutrient efficiency, drought tolerance, disease resistance**<sup>1</sup>
- Progress: **Epichloë** minus alkaloids
- **Tomato**: endophytes for insect management



- **Bioprospecting:**  
chemotherapy medication e.g.  
**taxol** (*Taxomyces andreanae*)
- **Metabolic diversity: plastic  
degradation** (*Pestalotiopsis*)<sup>1</sup>



<sup>1</sup> Russell et al. 2011

# The Future of Plant Microbial Ecology

From individuals to  
**Holobionts:** new  
understanding of  
basic ecological unit



