Growing confidence in forestry's future Research Programme

SCION
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Ecosystem genomics – lessons from other sectors

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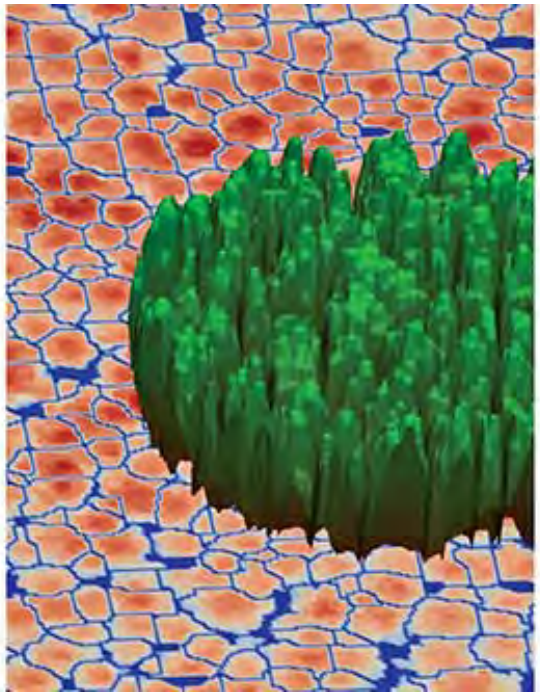


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Humans are not alone

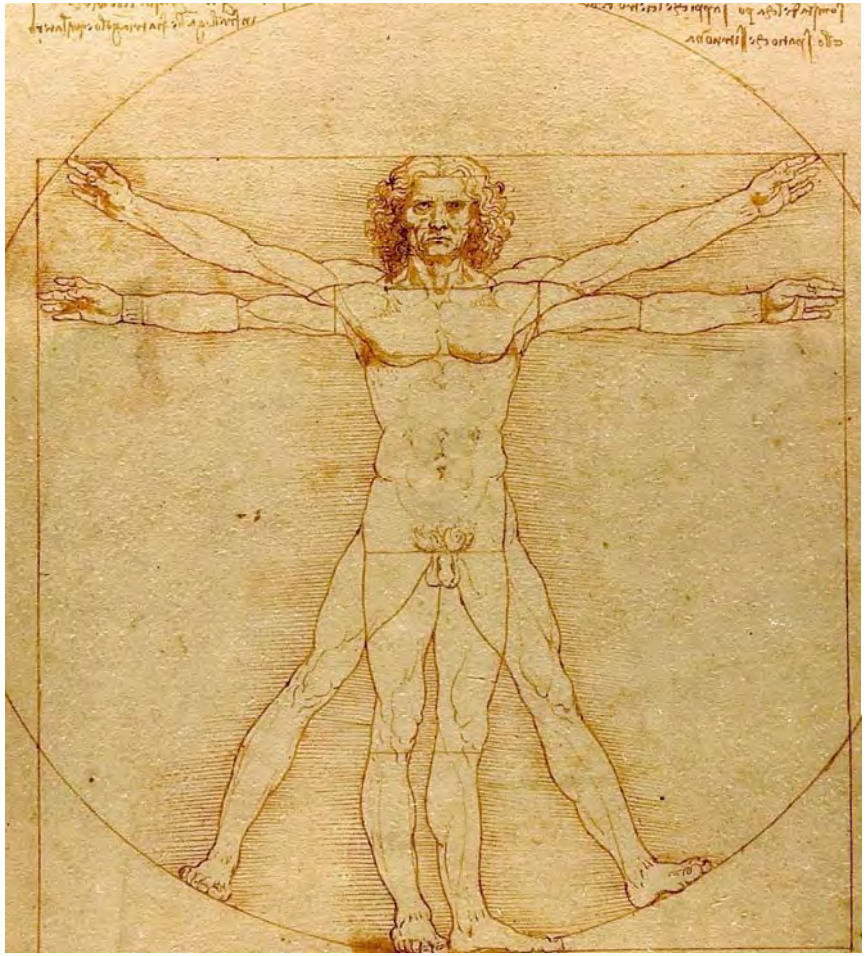
- We share our bodies with microorganisms.
- Spent decades and trillions of $ trying to eradicate.

- Small fraction of microbes on & in us are pathogenic.

What other microbes live on and in us, and *what do they do*?

Human microbiome project

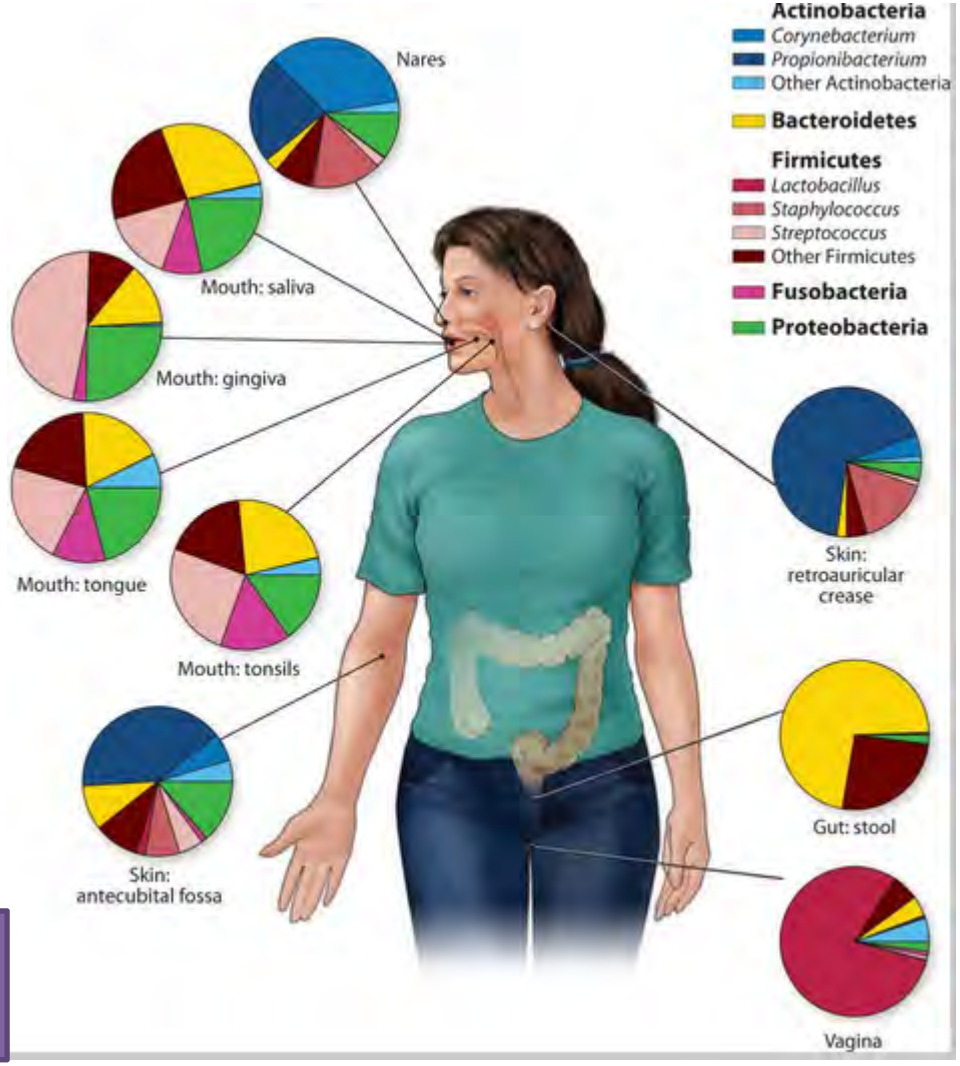
- 2008, 5 year, $115 Million ‘feasibility’ study.
- Define ‘what's there’, metabolism, links with human health.
- 242 volunteers.
- 5000 samples: mouth, nose, skin, gut, lower intestine (stool), vagina.



Results are so profound and unexpected, its still going.
Revolutionising human health and medicine.

Human microbiome project

- > 10,000 bacterial species;
  100 million million cells
- 1:1 microbial:human cells
- Each body part is a distinct ‘ecosystem’.
- Vary by individual, health, age, gender, etc.

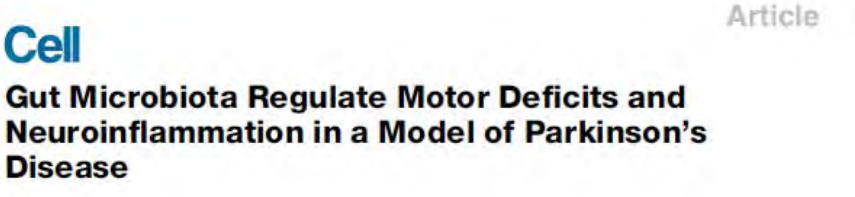


All ecosystems x human genome
= entire ‘holobiome’

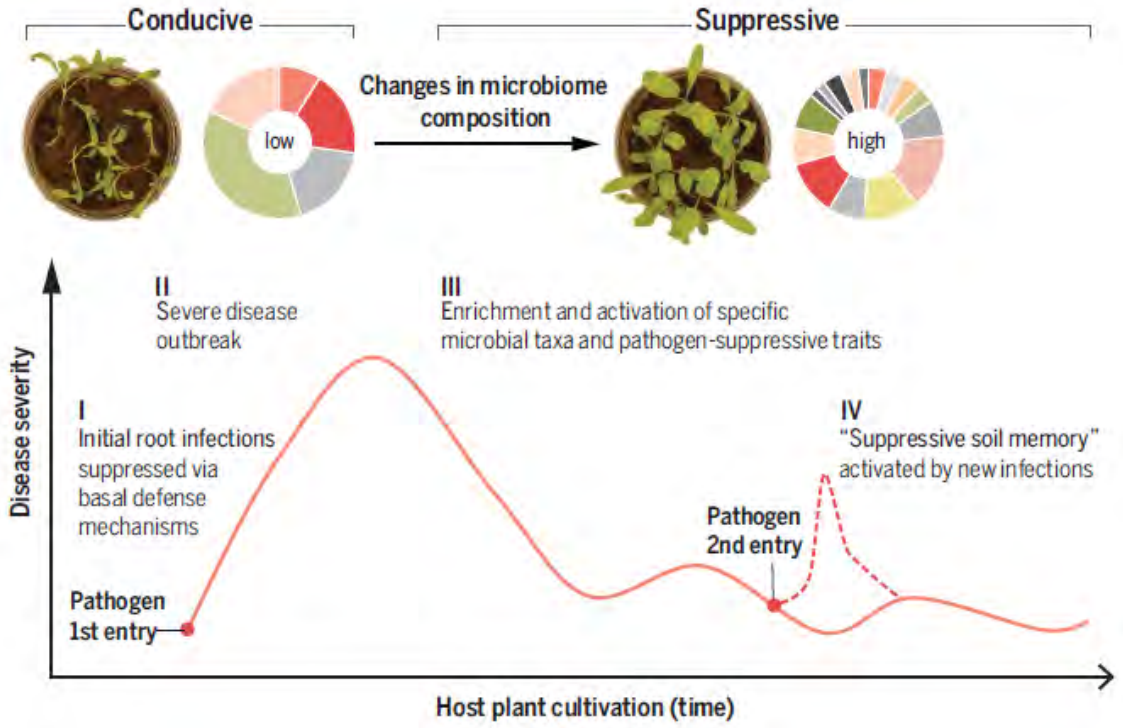
Functional significance?

Gut ecosystem

- 1000 species of and **3.3 million** genes
- Dwarfs the entire human genome's **23,000** genes
- Microbes contribute more genes for human survival than humans own genes.
- Vitamin production, complex decomposition, steroid & hormone.
- Rather than evolving new functions, we have *acquired microbial symbionts* that conduct specialised functions for us.



Where the gut goes, soils and plants can follow…



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ECOLOGY

Soil immune responses

Soil microbiomes may be harnessed for plant health

frontiers in MICROBIOLOGY

PERSPECTIVE ARTICLE
published: 03 December 2013
doi: 10.3389/fmicb.2013.00355

Bespoke microbiome therapy to manage plant diseases

Murali Gopal*, Alka Gupta and George V. Thomas

Microbiology Section, Central Plantation Crops Research Institute, Kudlu, Kasaragod, India

Vineyard microbiome → grape quality

The Soil Microbiome Influences Grapevine-Associated Microbiota

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Microbial *terroir* for wine grapes

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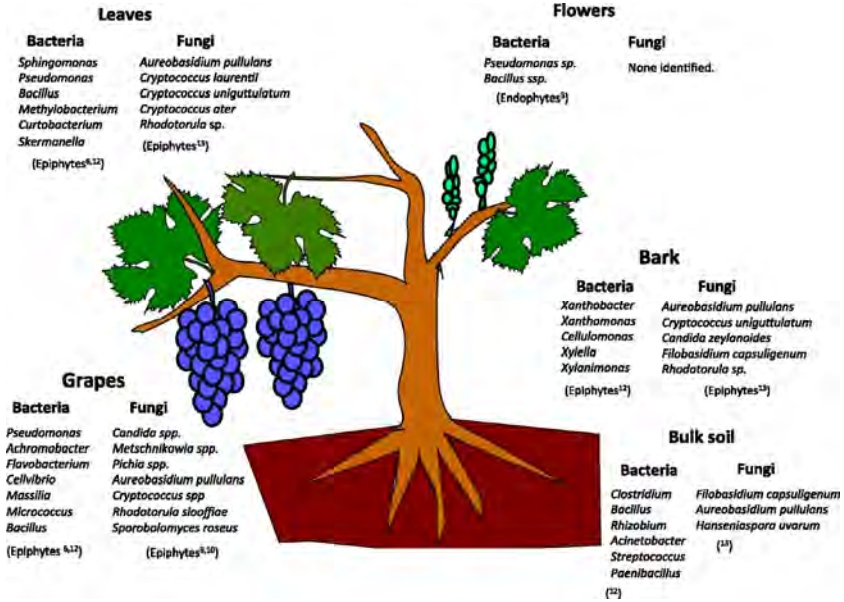
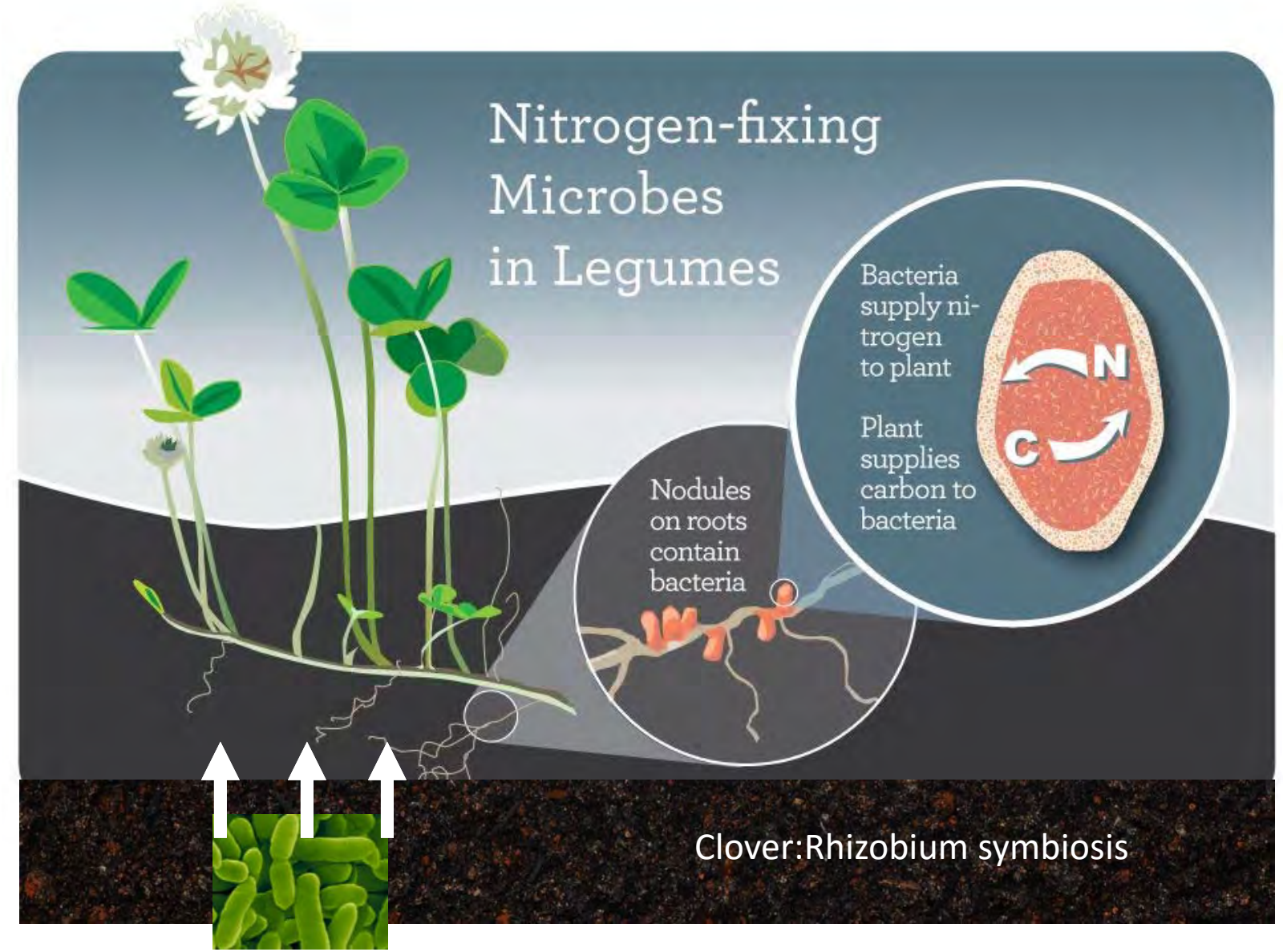
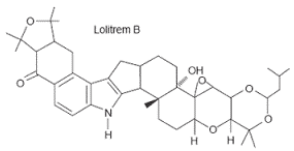


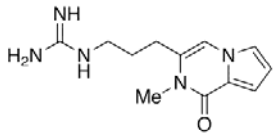
Dairy sector based on a pasture ‘holobiome’

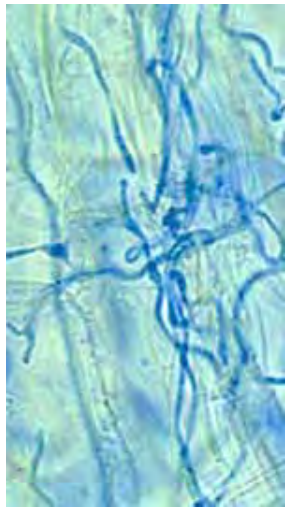
Clover ecosystem: supplies nitrogen to ryegrass



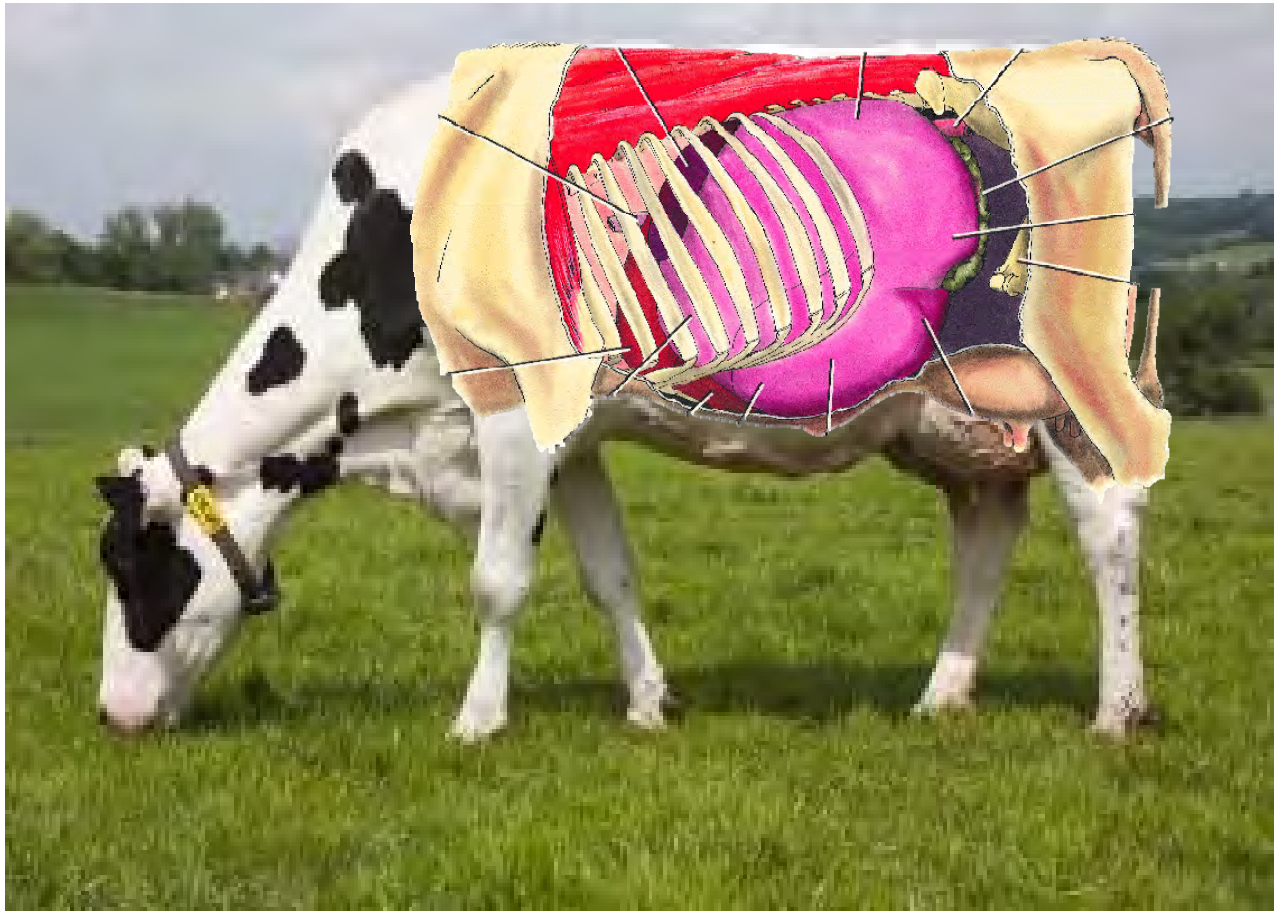
Ryegrass ecosystem: biomass for livestock







Livestock ecosystem: fiber and food



Rumen

2×10^{24} organisms

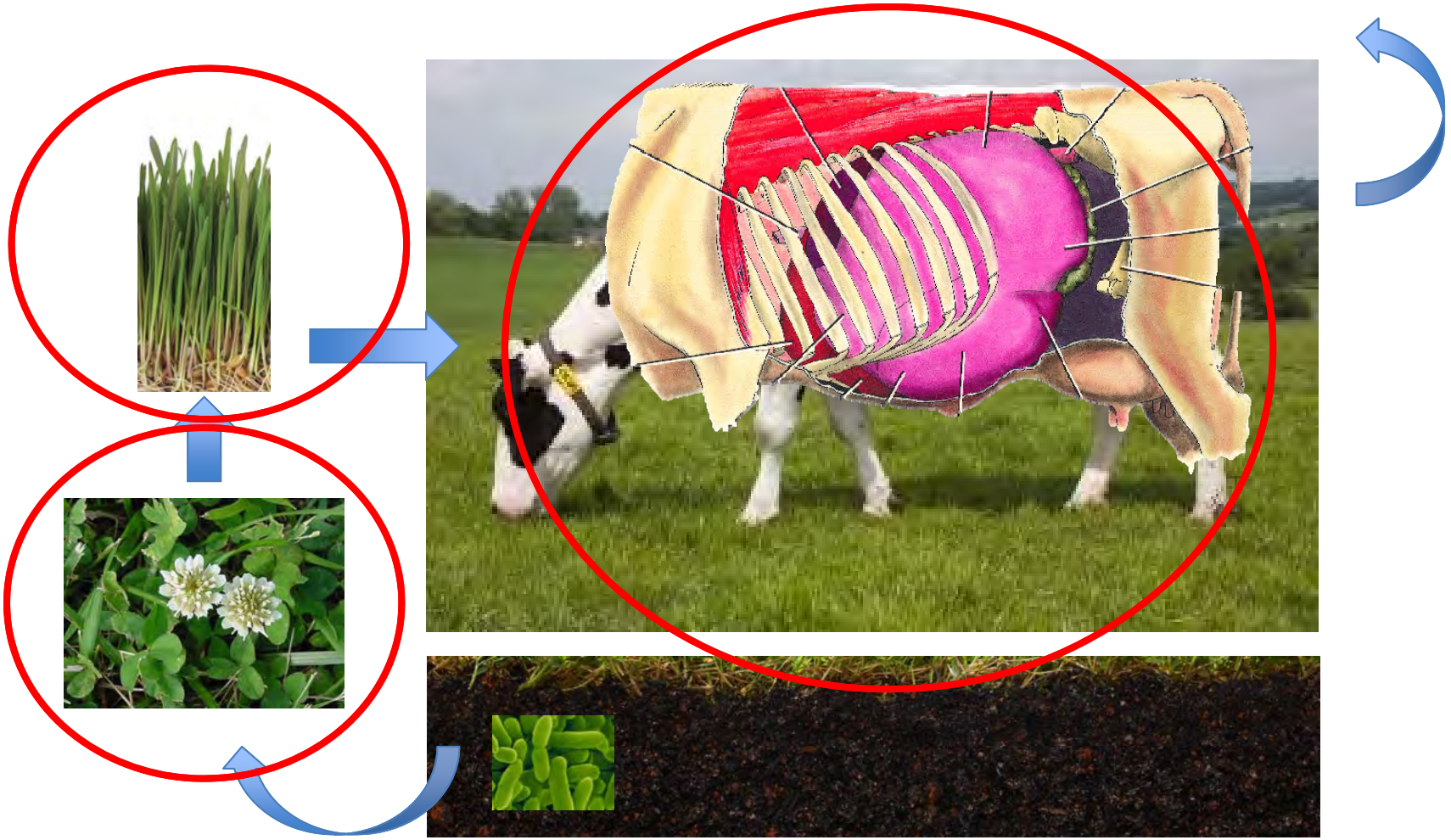
Convert plants to ‘metabolisable energy’.

Unwanted byproducts

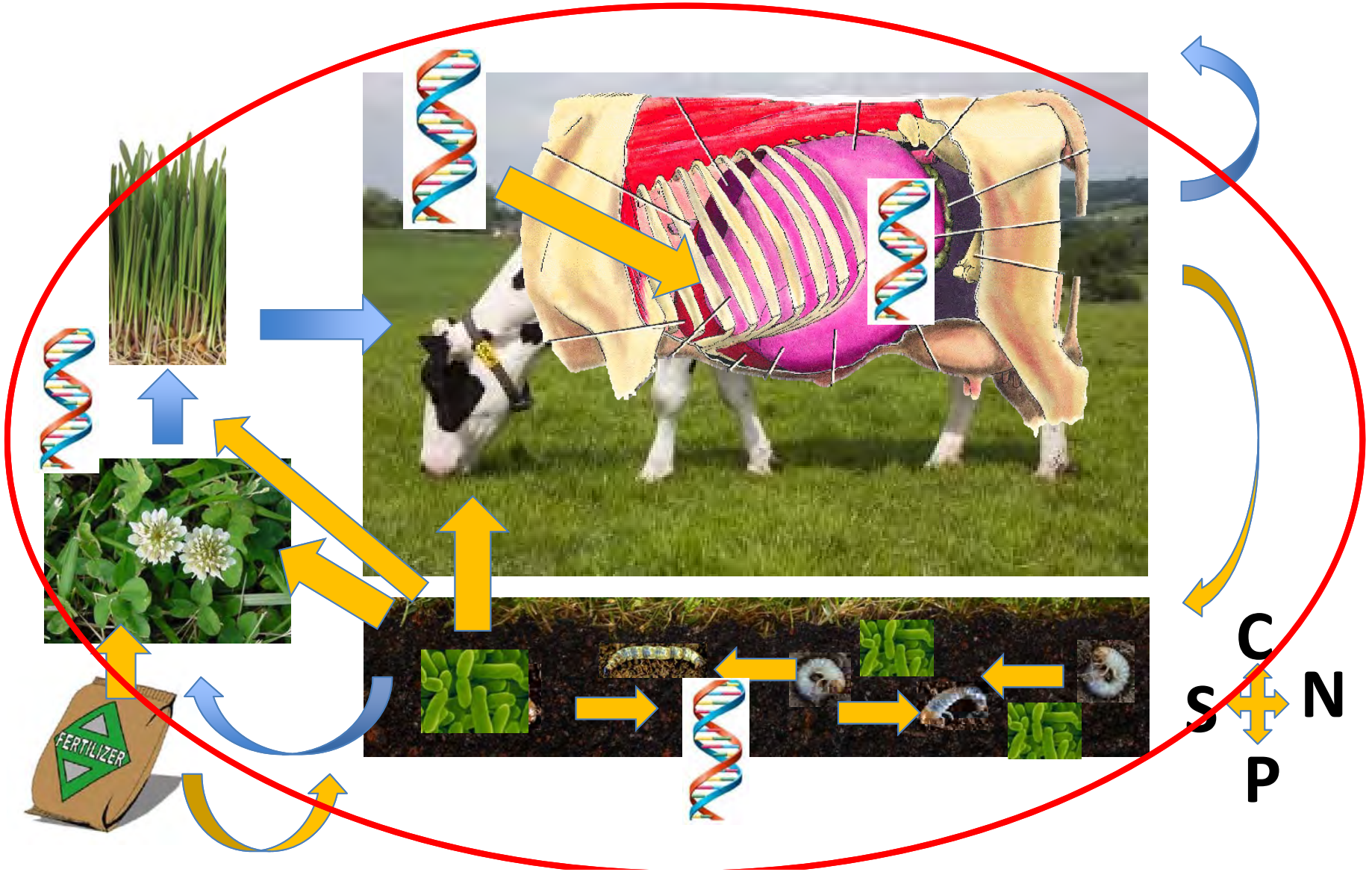
Huge $:

1. increase feed efficiency and alter milk characteristics
2. reduce CH_4

Meta-ecosystem: integration of several ecosystems



Sub-systems highly coupled and interdependent = holobiome



Dairy Sector: Identifying opportunities for multiple ecosystem interactions

- Experimentally testing interactions among bovine genomes x plant genomes x soil genomes x env (G^3xE)

"Understanding the connections and interactions between soil, water, plant and animal microbiomes to form innovative microbiome-informed technologies to drive greater agricultural productivity with reduced environmental impacts".

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Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

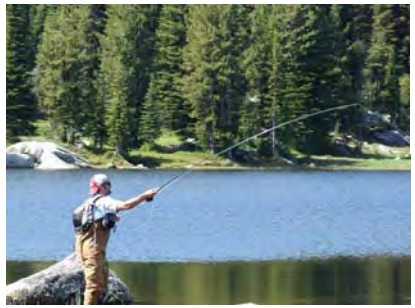
DairyNZ

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

Landcare Research
Manaaki Whenua

Plant & Food Research
Rangahau Ahumara Kai

Microbial ecosystems underpin forest success



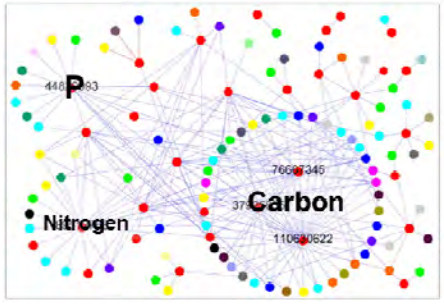
Social and cultural “licence to operate’ and market access

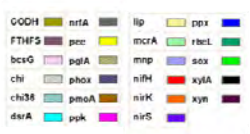
Tree Pests and diseases

Climate change, land use change, soil ecosystem services, & NRM

Invasion of weeds and pests

Plant cultivar X Microbiome X Environment





Biogeochemistry C, N, P, S,

Massive opportunity to manage the forest holobiome

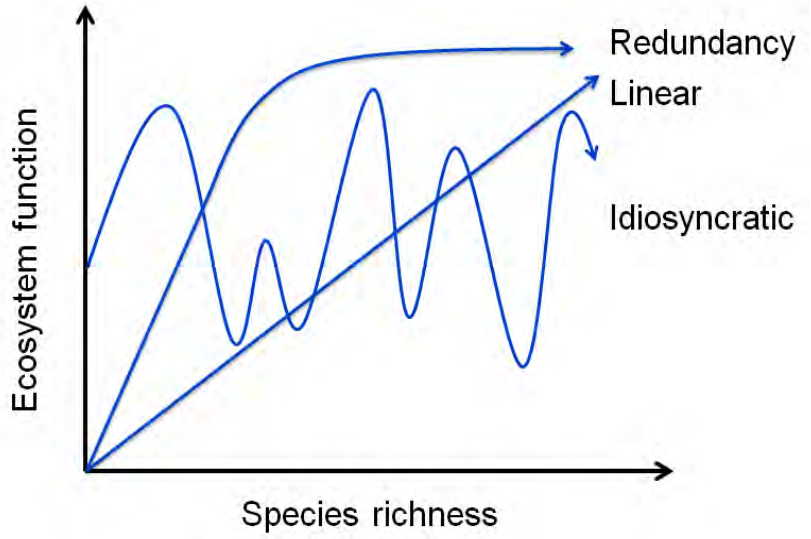
Assess ecology within many sub-ecosystems and expand to entire forest holobiome

- Huge potential for genetic gain across a wide range of functions (nutrients, disease, NRM).

If it was easy, it would have been done. Its not easy….

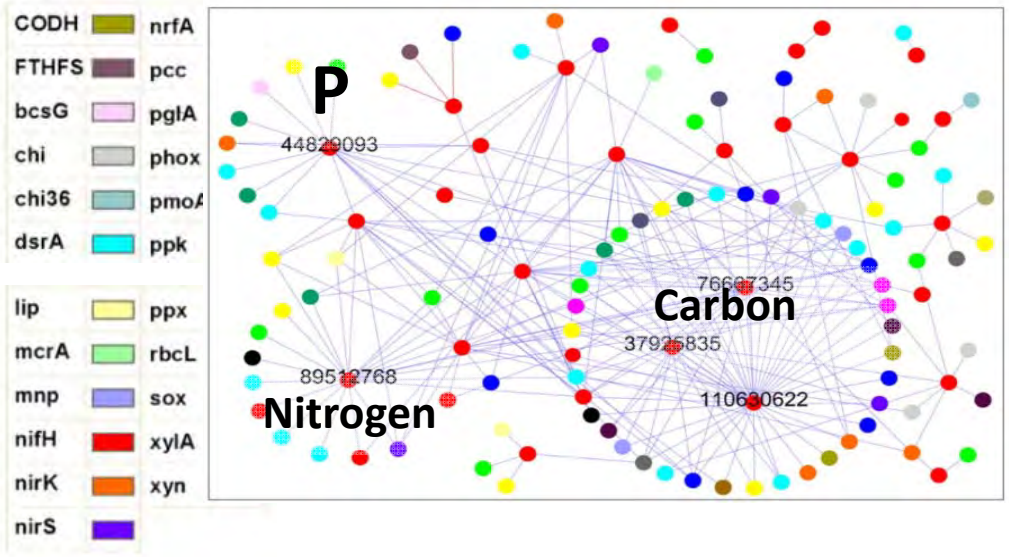
- Massive richness of species and highly complex ecosystems.
- Interactions often not predictable.
- Multiple process with emergent properties

Functions do not exist in isolation



Species-function relationships:

- Not immediately apparent
- Difficult to assess
- Don't follow linear responses



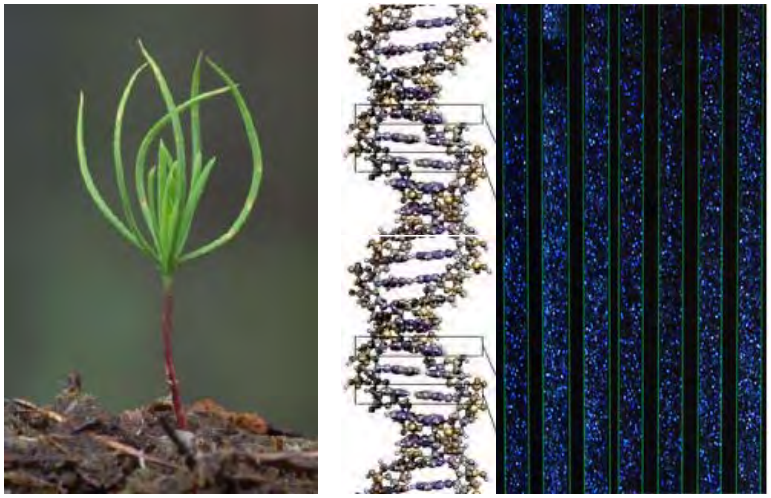
Ecosystem phenotype / functional state

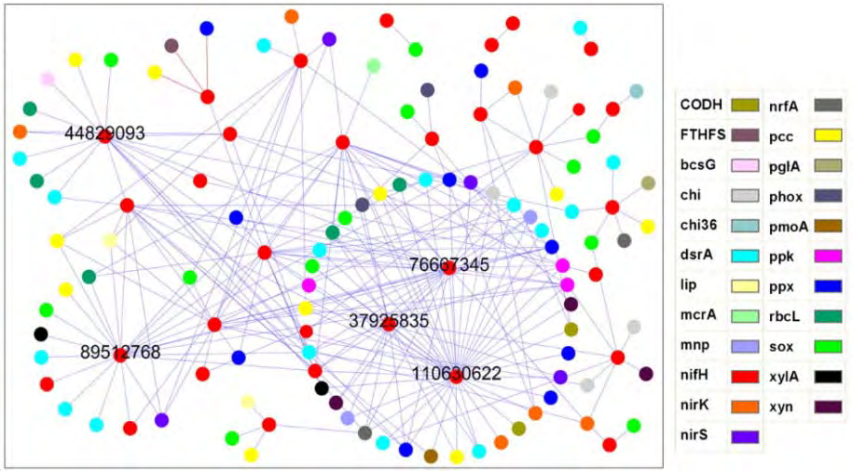
- Emergent outcome of all linked processes and interactions
- High functional integration at an ecosystem level

How do we get to this level of understanding?

Approach: Environmental Genomics

- Reconstruct each sub-ecosystems from the gene up.
- Approaches based on function, species, or combination.
- Complex systems analysis and network theory to account for process coupling and interdependencies.

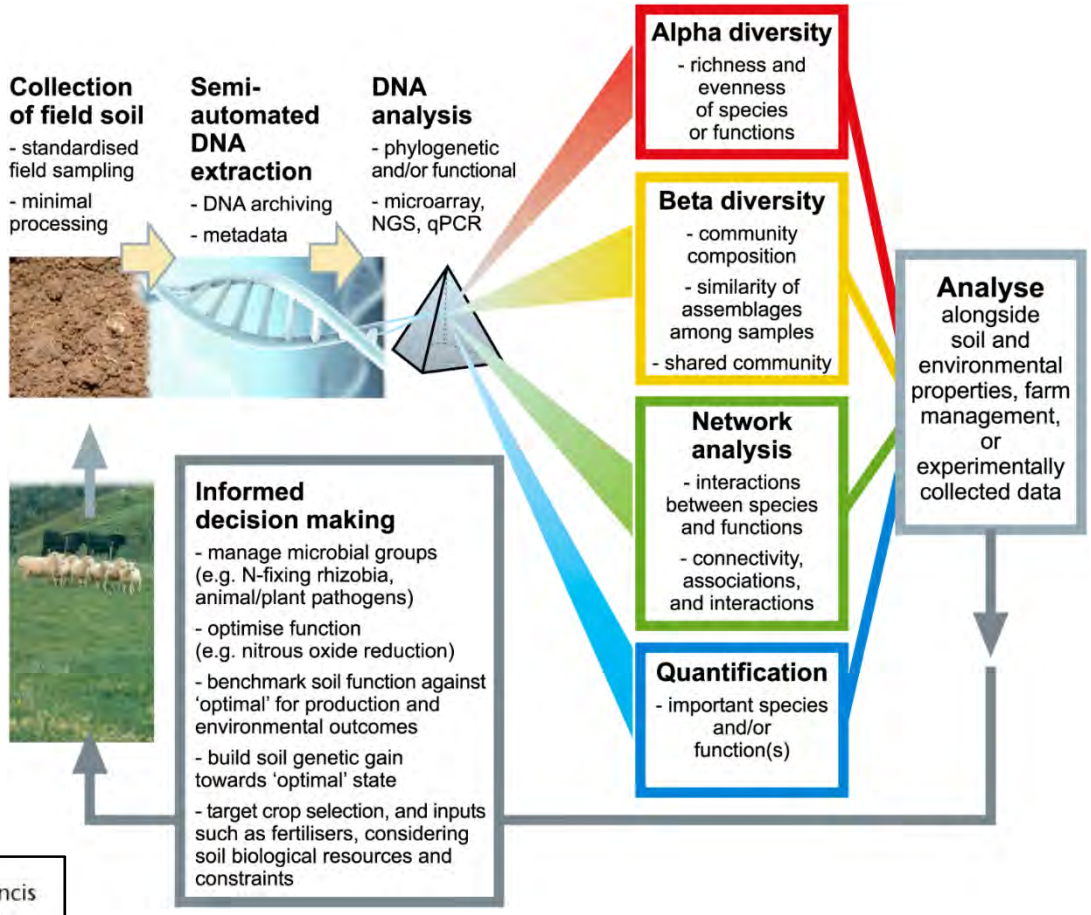




Building ‘genetic gain’ in pasture ecosystems

– Recently described a pipeline / approach to build ‘genetic gain’ in pastoral soils

Wakelin et al., 2016



NEW ZEALAND JOURNAL OF AGRICULTURAL RESEARCH, 2016
VOL. 59, NO. 4, 333–350
http://dx.doi.org/10.1080/00288233.2016.1209529
Taylor & Francis
Taylor & Francis Group

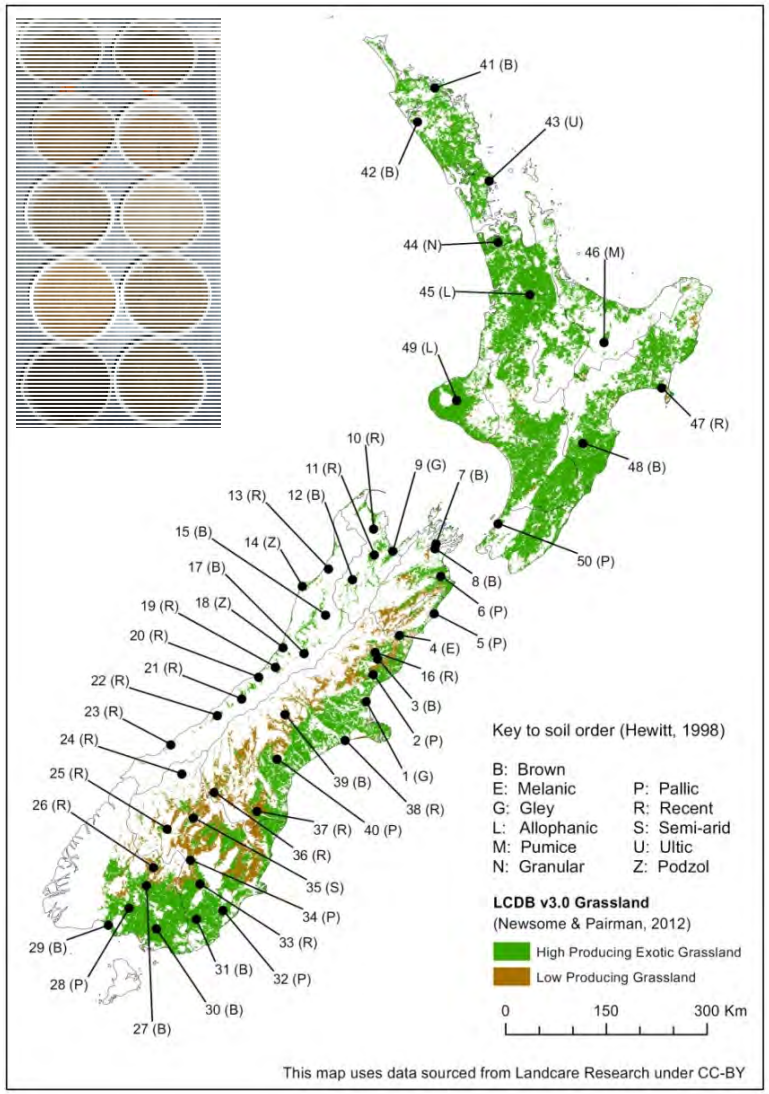
RESEARCH ARTICLE

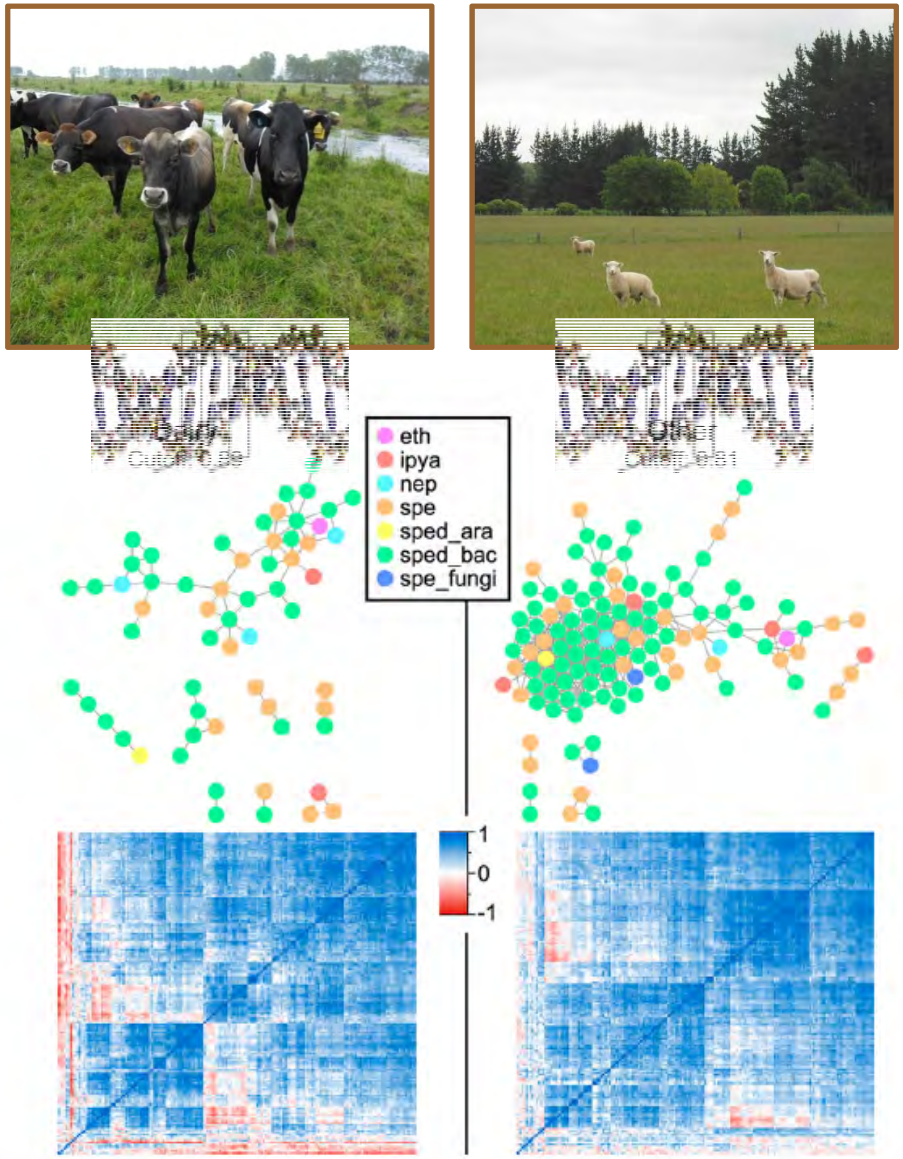
Analysis of soil eDNA functional genes: potential to increase profitability and sustainability of pastoral agriculture

SA Wakelin[a], VM Cave[a], BE Dignam[a,b], C D'Ath[a], M Tourna[a,c], LM Condron[b,d], J Zhou[e,f,g], JD Van Nostrand[e] and M O'Callaghan[a]

Translatable to other land-uses

Example: Environmental genomics in NZ pastures

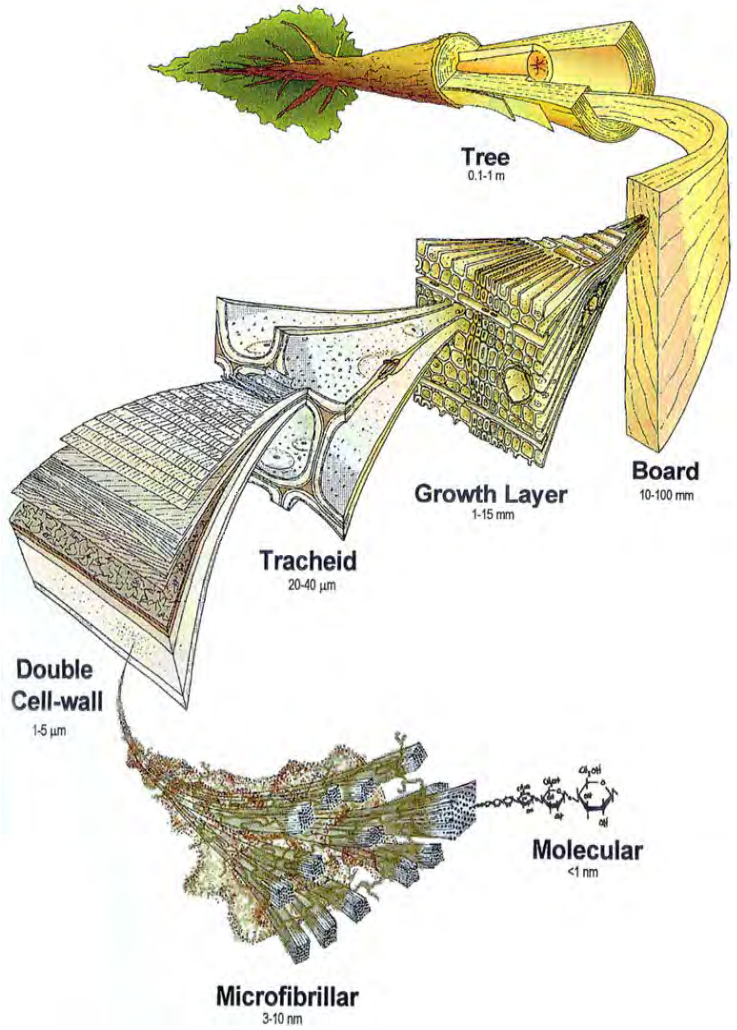




Current opportunities

Determining the role of the ‘pine microbiome’ – from the plant to the soil

- Direct plant productivity – beneficial v deleterious biota
- Stress tolerance, environmentally resilient forests
- Wood formation and quality (cambial, root, soil microbiomes)
- Root-microbe-soil interactions for water and fertiliser use efficiency
- Disease resistant forest soils (e.g. *Phytophthora* resistant)



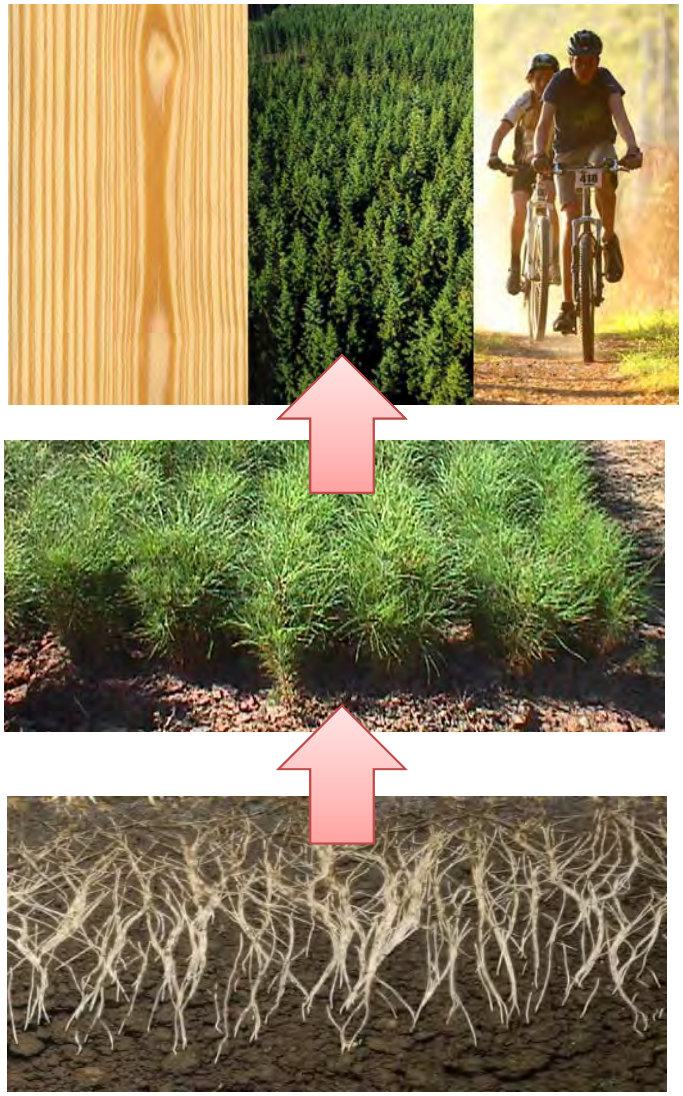
Future opportunities

Introduction of novel plant microorganism associations. New traits via the 2nd genome

Utilise knowledge of the soil microbiome x environment to inform planting (genotype) and silvicultural processes.

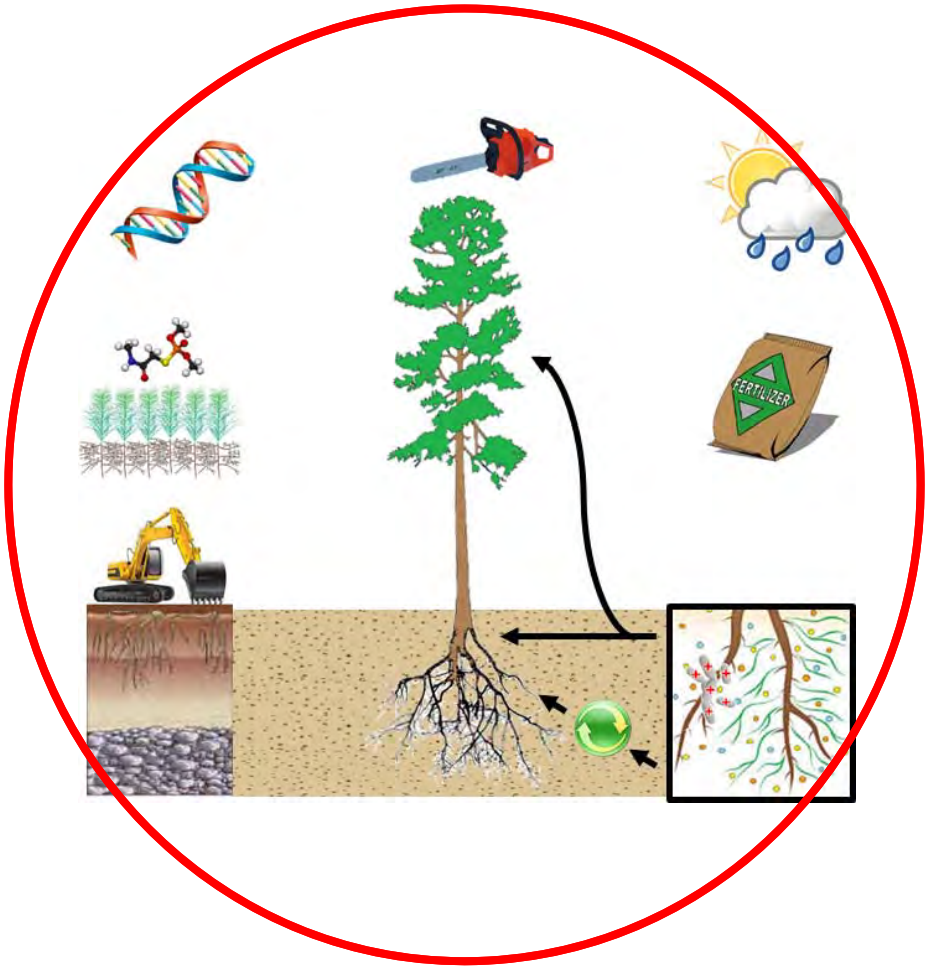
Provenance of wood/products from NZ forests – understanding ecosystem health and protection of native microbiota.

More profitable, resilient, sustainable, and socially acceptable forestry.



Ecological genomics for planted forests

- Like the human genome, there will be a lot of things to discover, that we don't even know to look for yet.
- Many things we know that we don't know.
- But it's the unknown unknowns that will have the most disruptive influence on opportunities for future forest.
- Start now, to build foundation-base for research in 5-10 years time….



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