Biotechnology and tree breeding

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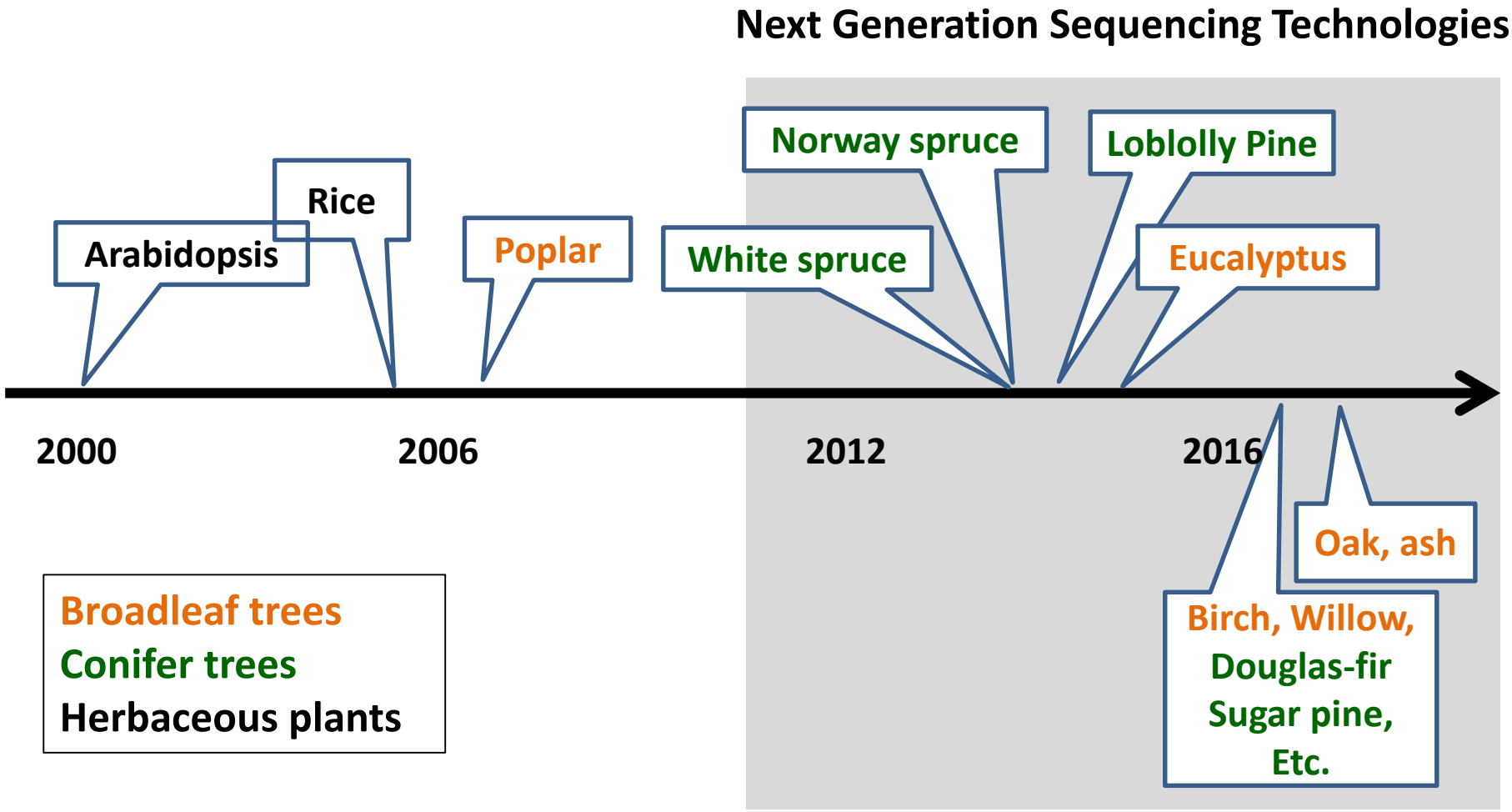
Eucalyptus yields from intensive Tree Improvement and silviculture

Decade	1970	1980	1990	2000
Wood volume (m3 /ha / year)	30	35	45	50+
Wood fibre yield (dry tons /ha /year)	6.4	8.1	10.2	11.3

Sequencing of Forest Tree Genomes



Outline

- Recent Developments in Forest Genomics
- Matching Technology with Needs
- Conclusions

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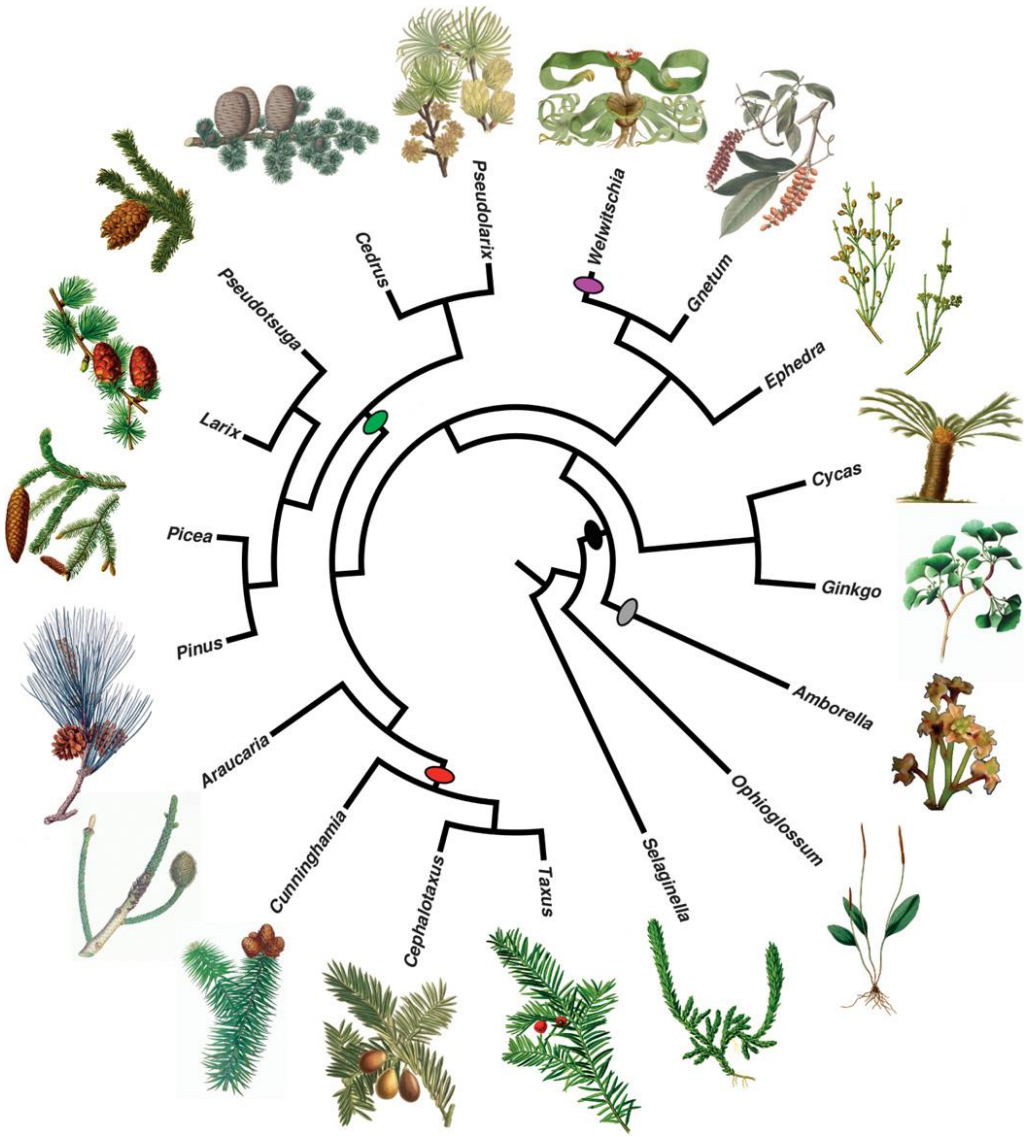
Recent Developments in Forest Genomics

- Knowledge creation
- Research and impacts in forest productivity and health

Whole Genome Duplications (WGD) in Conifers

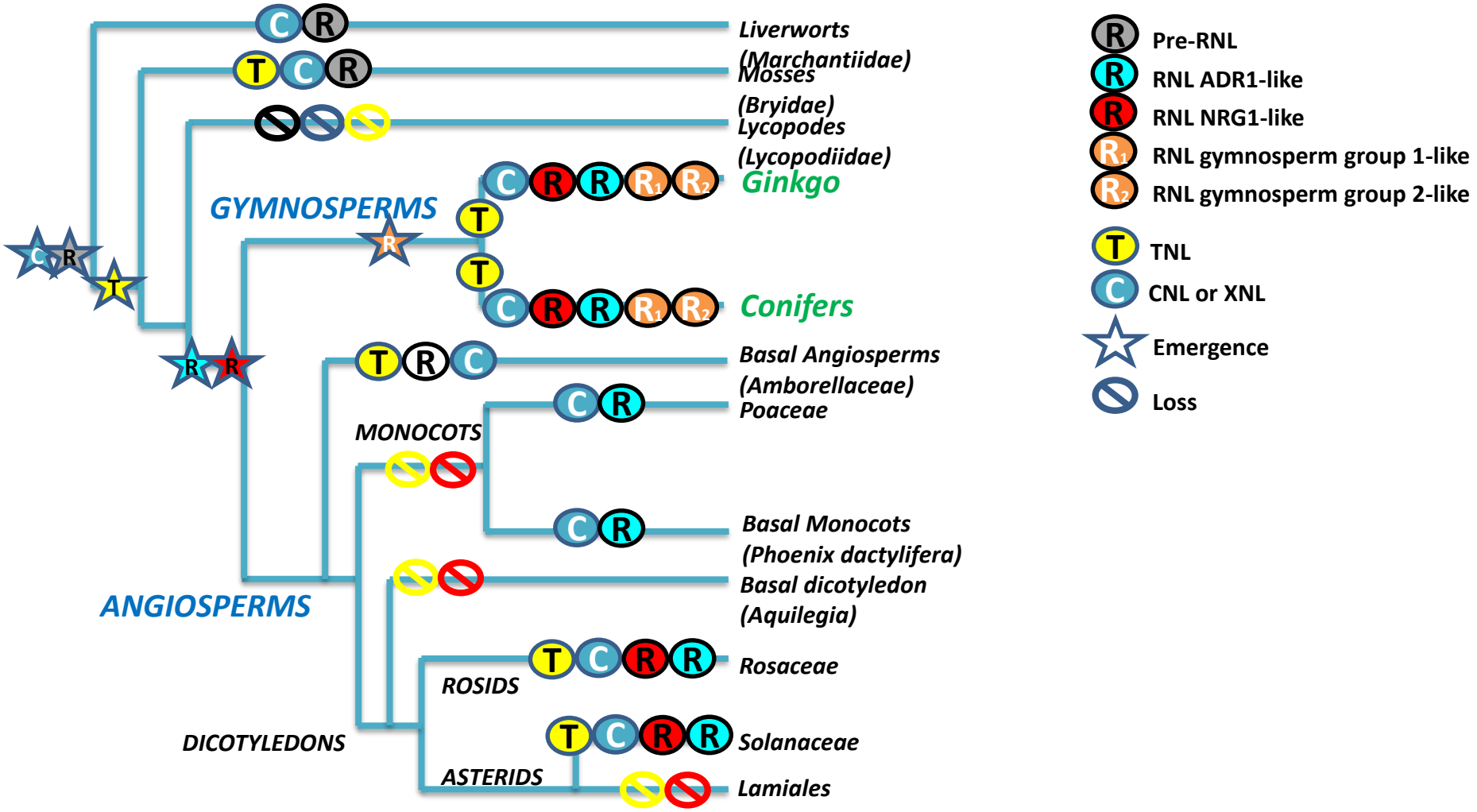
Ovals correspond to inferred locations of WGD events;

- black, seed plant;
- gray, angiosperm;
- purple, *Welwitschia*;
- green, Pinaceae (Pine family);
- red, cupressacea (cypress family).



Zheng Li et al. Sci Adv 2015;1:e1501084

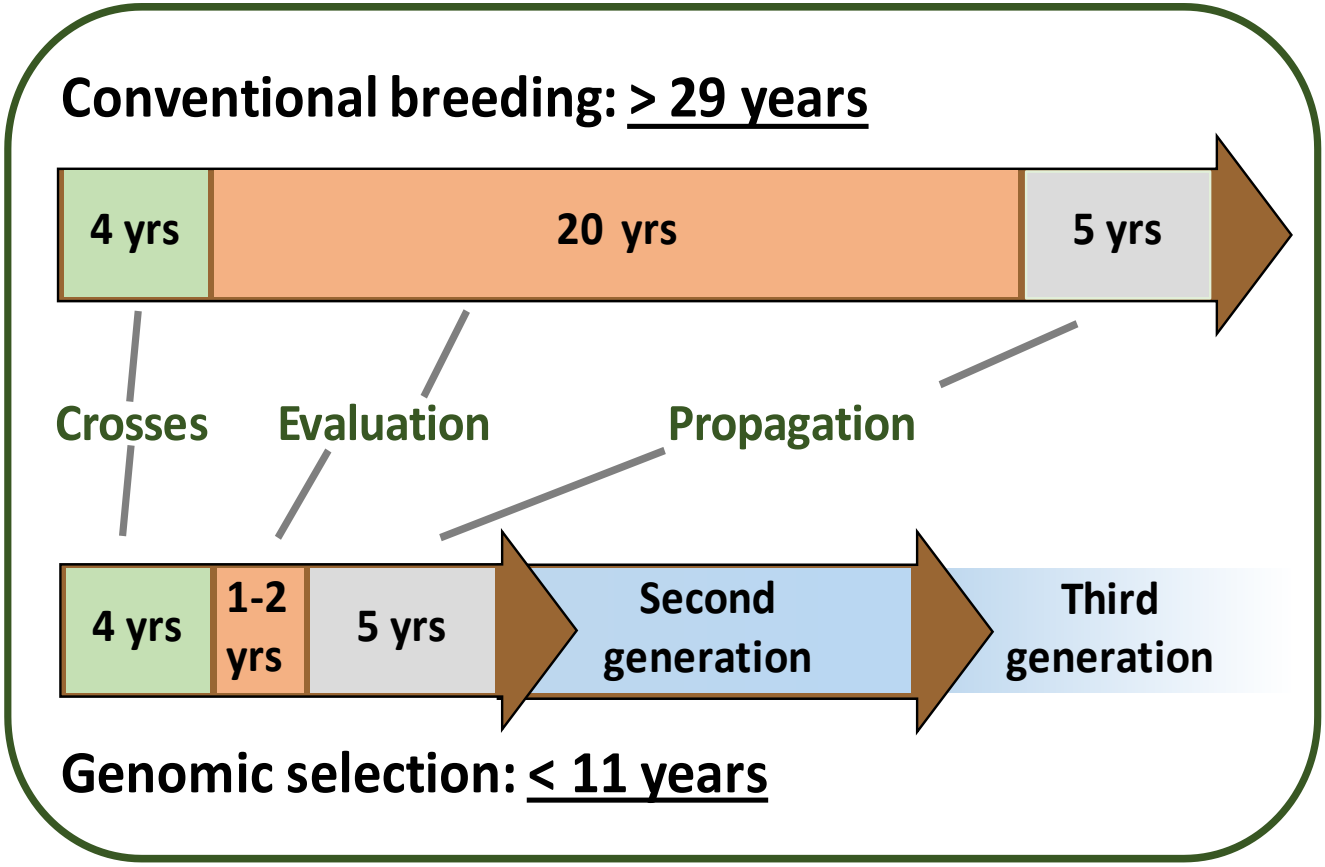
Evolution of Disease Resistance genes



Genomic Selection to Accelerate Tree Breeding

Expected impact of genomics on the duration of conifer breeding cycles.

Genetic gain:
2.5 – 3 times more gain per year is expected (study in white spruce)



A Case Study: Genomic Selection in White Spruce

Advanced-Breeding Population

Trait	Accuracy		Gain (5% S.I.)		Efficiency
	Conventional	GS	Conventional	GS	GS/C (%)
Height (cm)	0.80	0.71	106	100	94%
Diameter (DBH) (cm)	0.84	0.73	7.98	7.28	91%
Wood density ($Kg/m^{3)}$	0.88	0.80	23.8	21.2	89%
Cellulose microfibril angle (degrees)	0.86	0.77	2.62	2.48	95%

- **Validates in black spruce**
- **We have learned the parameters that determine GS performance**

Genomics Informed Breeding in Sitka Spruce

A 3 year project funded by the BBSRC

(Biotechnology and Biological Sciences Research Council of the UK)

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Sitka *Spruced*

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Sitka Spruce, Brecon Beacons. Image credit: Professor John MacKay.

PROJECT OVERVIEW

The Sitka *Spruced* project aims to create novel capacity to increase the rates of genetic gain in the UK's breeding programme. Selective breeding is effective for increasing yields in Sitka spruce but it takes 30 years to select and propagate new varieties. Sitka *Spruced* will develop Genomic Selection methods aiming to shorten the breeding process and increase the rate of yield gains more than two-fold. The proposed research will develop large-scale genotyping capacity, a genetic linkage map for Sitka spruce, and large training set for predictive genomics model development. We will use this platform to investigate issues of genomic prediction accuracy, models for both yield and wood quality traits, genotype imputation, resistance to damaging insects.

PROJECT PARTNERS

Sitka *Spruced* is a collaboration of the University of Oxford, the University of Edinburgh (Roslin Institute) and Forest Research (an Agency of the Forestry Commission). It is funded by BBSRC and a group of forest and wood processing industries.

Susceptible

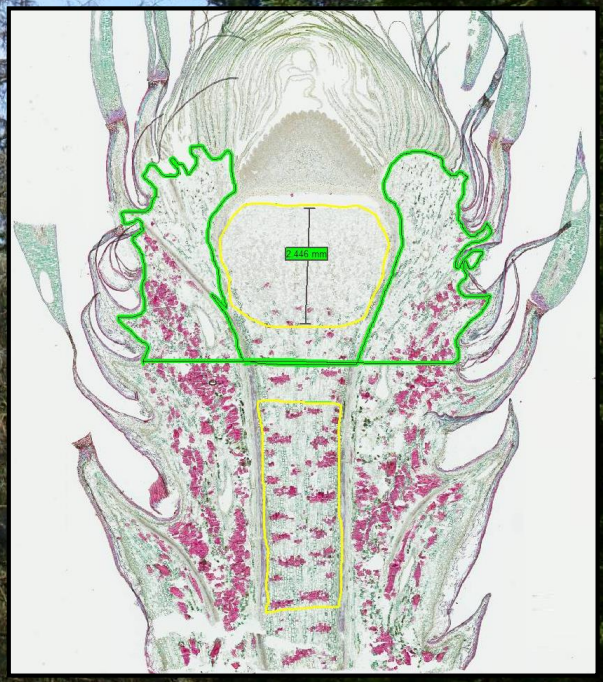
Recovering

Dead

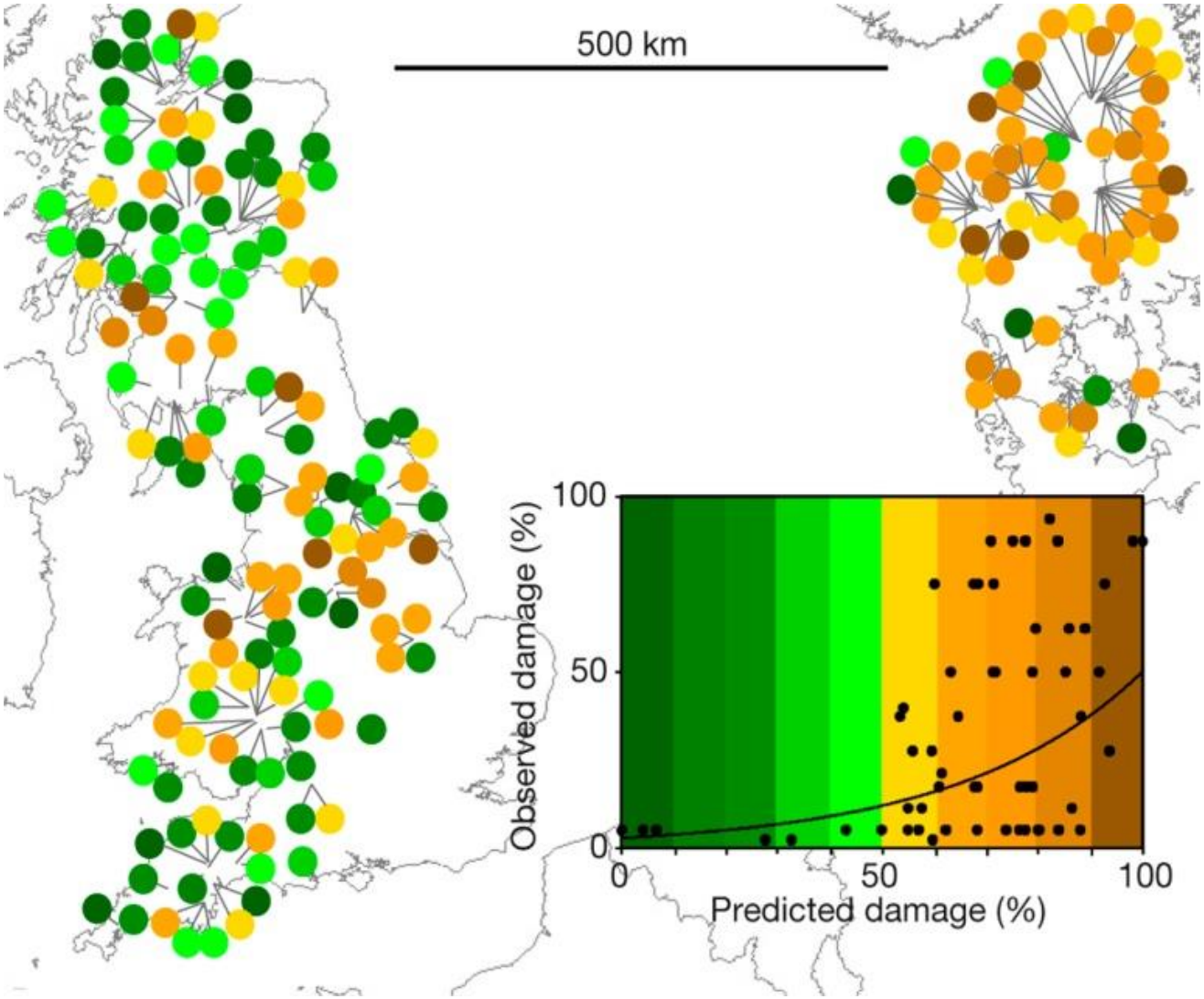
Resistant

Spruce Budworm: Resistance compounds		
	Piceol	Pungenol
Heritability	0.66 ± 0.07	0.60 ± 0.08

Weevil resistance in Sitka



Predicted Ash Dieback damage scores in Great Britain and Denmark

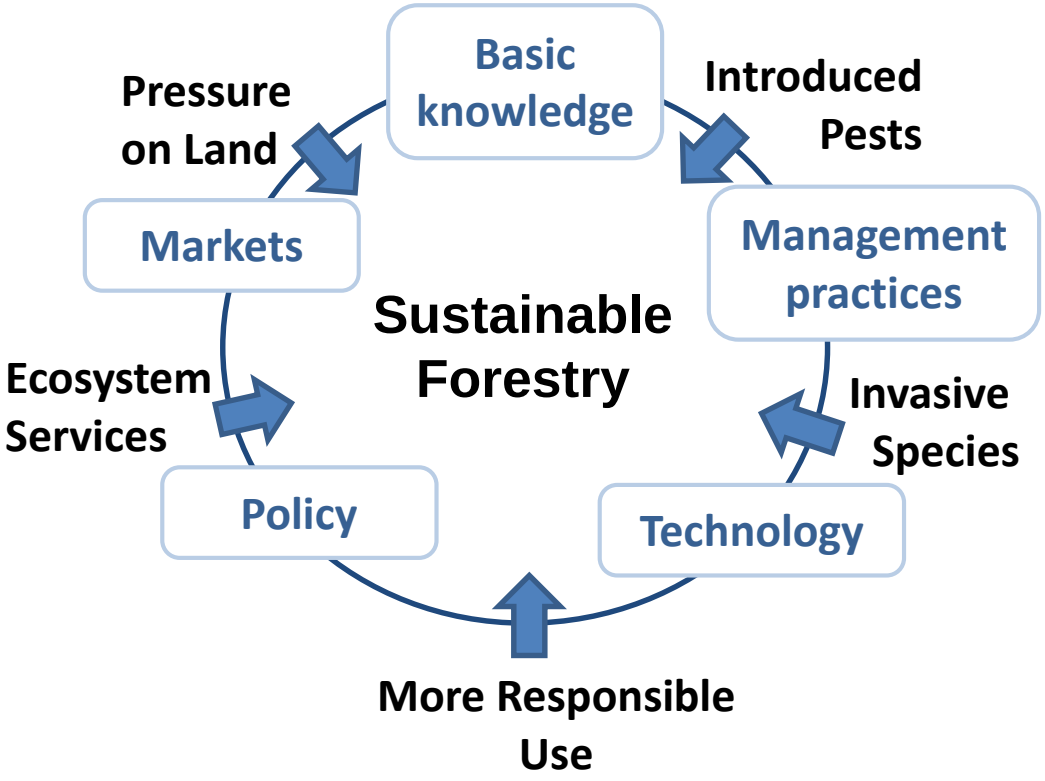


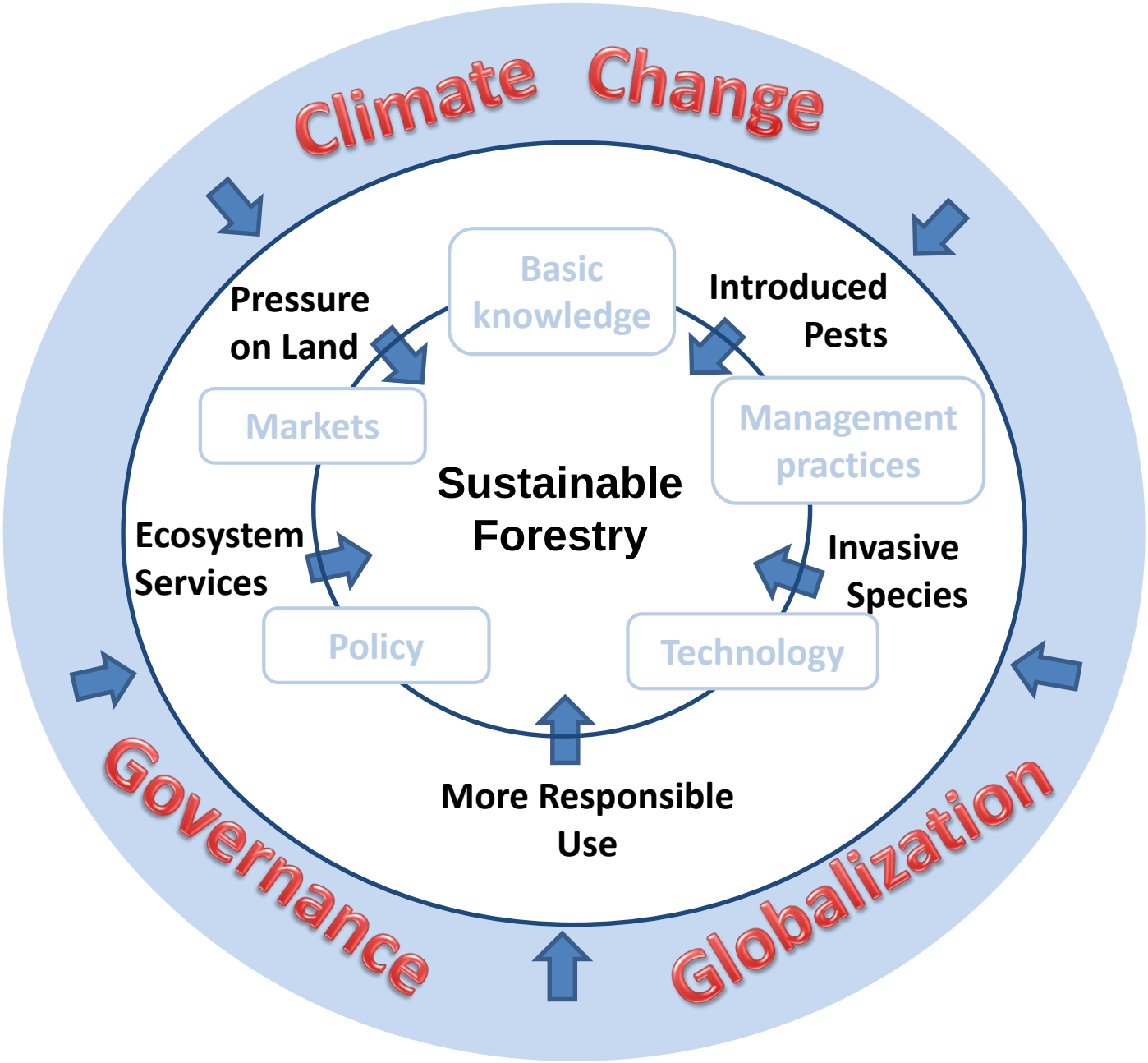
E S A Sollars *et al.* *Nature* 1–5 (2016) doi:10.1038/nature20786

Matching Technology with Needs

- 21st century challenges
- Forest Genetic Resources
- Other Technologies

21st Century Forestry: New Challenges




Climate Change
Basic knowledge
Introduced Pests
Management practices
Invasive Species
Technology
More Responsible Use
Policy
Ecosystem Services
Markets
Pressure on Land
Sustainable Forestry
Governance
Globalization

Forest Genetic Resources for Resilience and Sustainability

- Species and genetic diversity are the key
- Forest Genetic Resources (FGRs)
  - Ensure adaptability
  - Need better knowledge, management, and conservation
  - Several organisations are involved
- Role of DNA databases and marker technologies

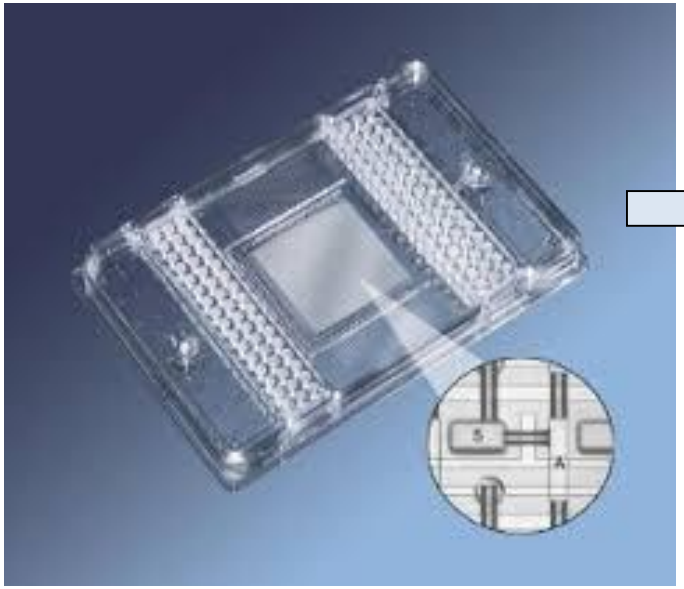
Forest Genetic Resources & DNA Markers

Species are diverse and needs are varied

- Mapping diversity, population structures, gene flow, tracing and tracking origins, conservation

Existing technologies enable:

- More efficient development of the knowledge base
- Flexible and efficient DNA testing



Other Technologies – Gene Editing

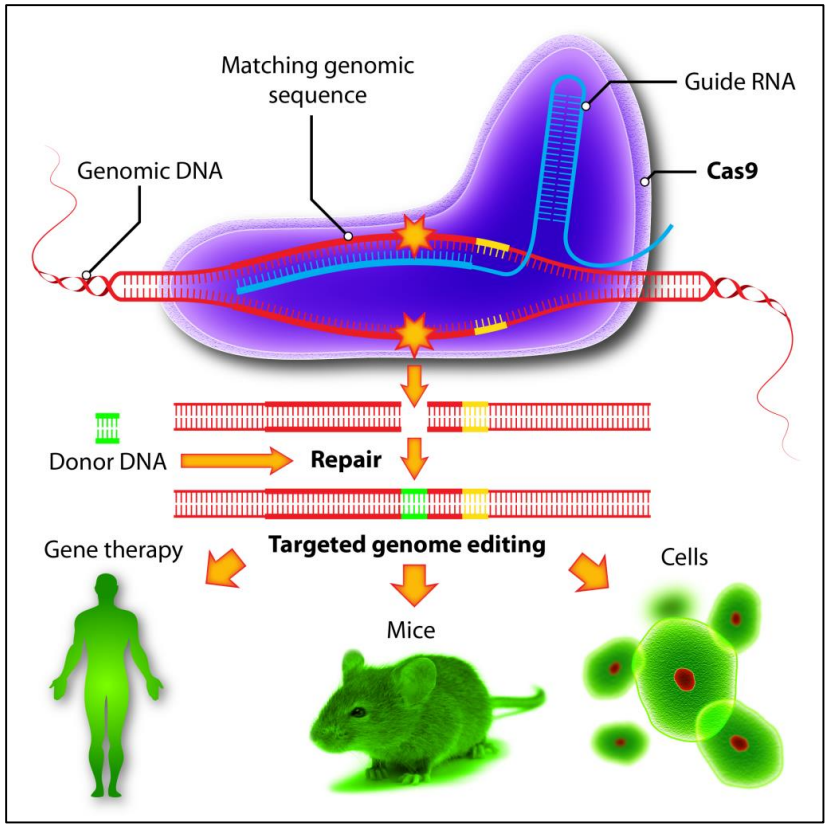
Genetic Modification for insect resistance by introduction of bacterial gene (Bt toxin gene)

Control

GM

CRISP/Cas for **Gene Editing**

- Potential for transgene-free plants
- **Trees** : demonstration studies; tests in disease resistance in poplar



Summary and Conclusions

1. Developments in genomics : rapid changes in tree breeding and forest health research
2. Next generation breeding : UK Sitka spruce
3. Increasing focus on adaptability and resilience : new opportunities from genomic technologies
4. UK organisations working together : coordination and adoption of new methods

Questions?