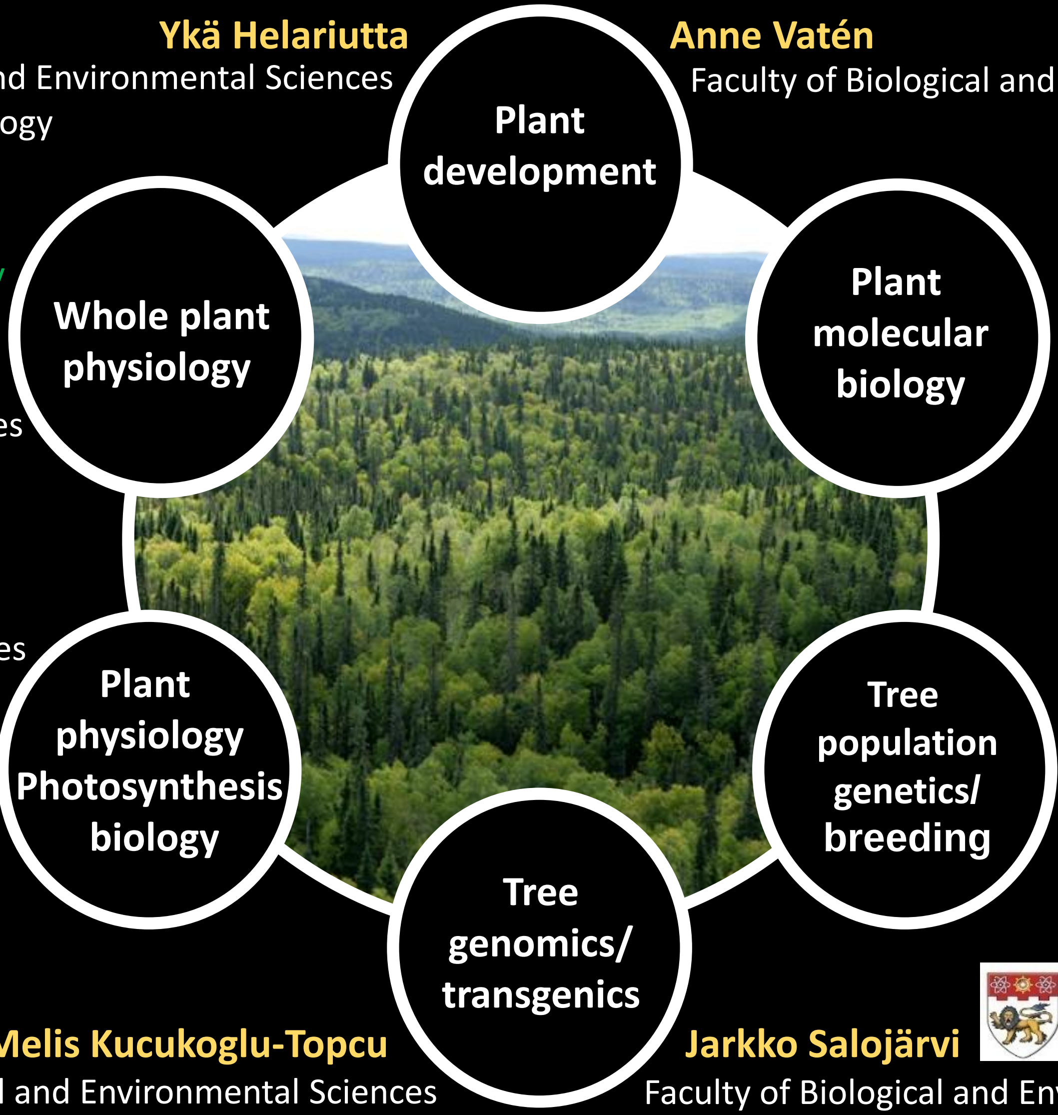
Koivun genetiikka

Ykä Helariutta

Kasvien kehitysbiologian professori

Helsingin yliopisto

Centre of Excellence of Tree Biology (2022-29), Academy of Finland



Ykä Helariutta
Faculty of Biological and Environmental Sciences
Institute of Biotechnology

Plant development

Anne Vatén
Faculty of Biological and Environmental Sciences

Faculty of Agriculture and Forestry
Teemu Hölttä
Maija Sierla
Faculty of Biological and Environmental Sciences

Whole plant physiology

Plant molecular biology

Faculty of Biological and Environmental Sciences
Ari Pekka Mähönen
Cezary Waszczak
Faculty of Biological and Environmental Sciences

Faculty of Biological and Environmental Sciences
Jaakko Kangasjärvi
Alexey Shapiguzov
Luke

Plant physiology Photosynthesis biology

Tree population genetics/ breeding

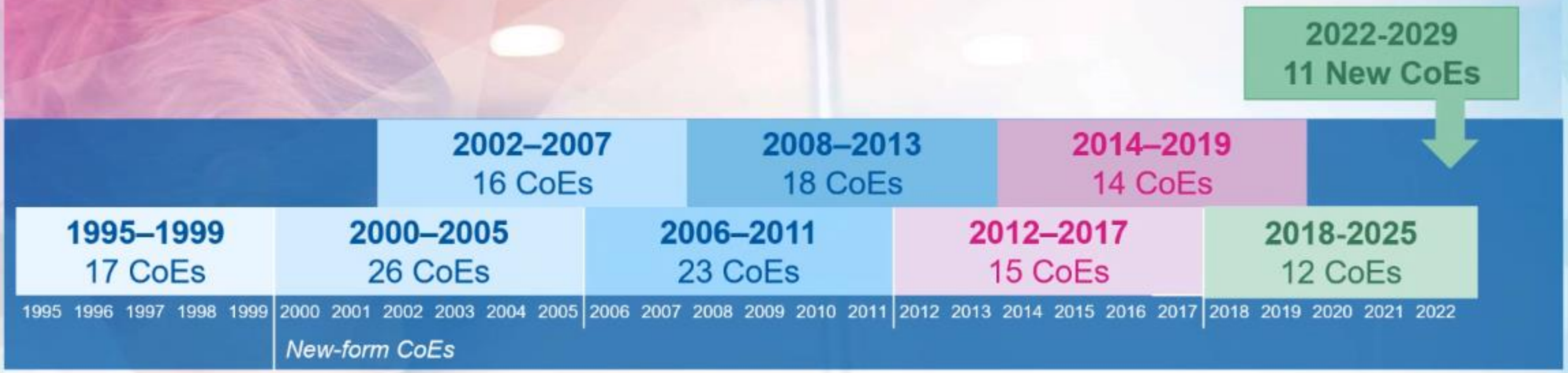
Faculty of Agriculture and Forestry
Tanja Pyhäjärvi
Kaisa Nieminen
Luke

Tree genomics/ transgenics

Melis Kucukoglu-Topcu
Faculty of Biological and Environmental Sciences

Jarkko Salojärvi
NANYANG TECHNOLOGICAL UNIVERSITY
Faculty of Biological and Environmental Sciences

Huippuyksikköohjelmat



- Based on competition, covers all disciplines, bottom-up

Johanna Myllyharju

A Large and Persistent Carbon Sink in the World's Forests

Yude Pan,[1]* Richard A. Birdsey,[1] Jingyun Fang,[2,3] Richard Houghton,[4] Pekka E. Kauppi,[5] Werner A. Kurz,[6] Oliver L. Phillips,[7] Anatoly Shvidenko,[8] Simon L. Lewis,[7] Josep G. Canadell,[9] Philippe Ciais,[10] Robert B. Jackson,[11] Stephen W. Pacala,[12] A. David McGuire,[13] Shilong Piao,[2] Aapo Rautiainen,[5] Stephen Sitch,[7] Daniel Hayes[14]

The terrestrial carbon sink has been large in recent decades, but its size and location remain uncertain. Using forest inventory data and long-term ecosystem carbon studies, we estimate a total forest sink of 2.4 ± 0.4 petagrams of carbon per year (Pg C year^{-1}) globally for 1990 to 2007. We also estimate a source of 1.3 ± 0.7 Pg C year^{-1} from tropical land-use change, consisting of a gross tropical deforestation emission of 2.9 ± 0.5 Pg C year^{-1} partially compensated by a carbon sink in tropical forest regrowth of 1.6 ± 0.5 Pg C year^{-1}. Together, the fluxes comprise a net global forest sink of 1.1 ± 0.8 Pg C year^{-1}, with tropical estimates having the largest uncertainties. Our total forest sink estimate is equivalent in magnitude to the terrestrial sink deduced from fossil fuel emissions and land-use change sources minus ocean and atmospheric sinks.

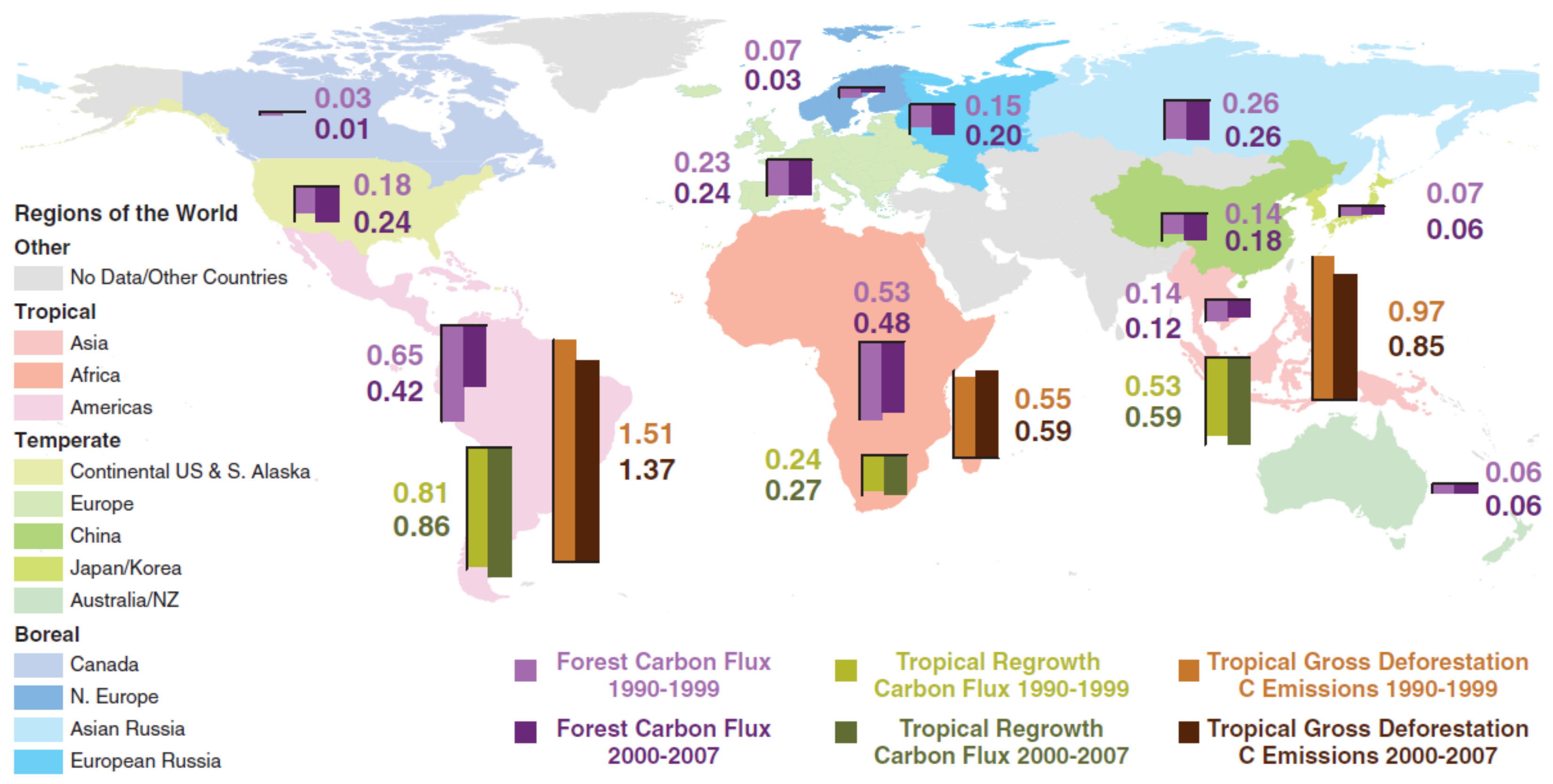
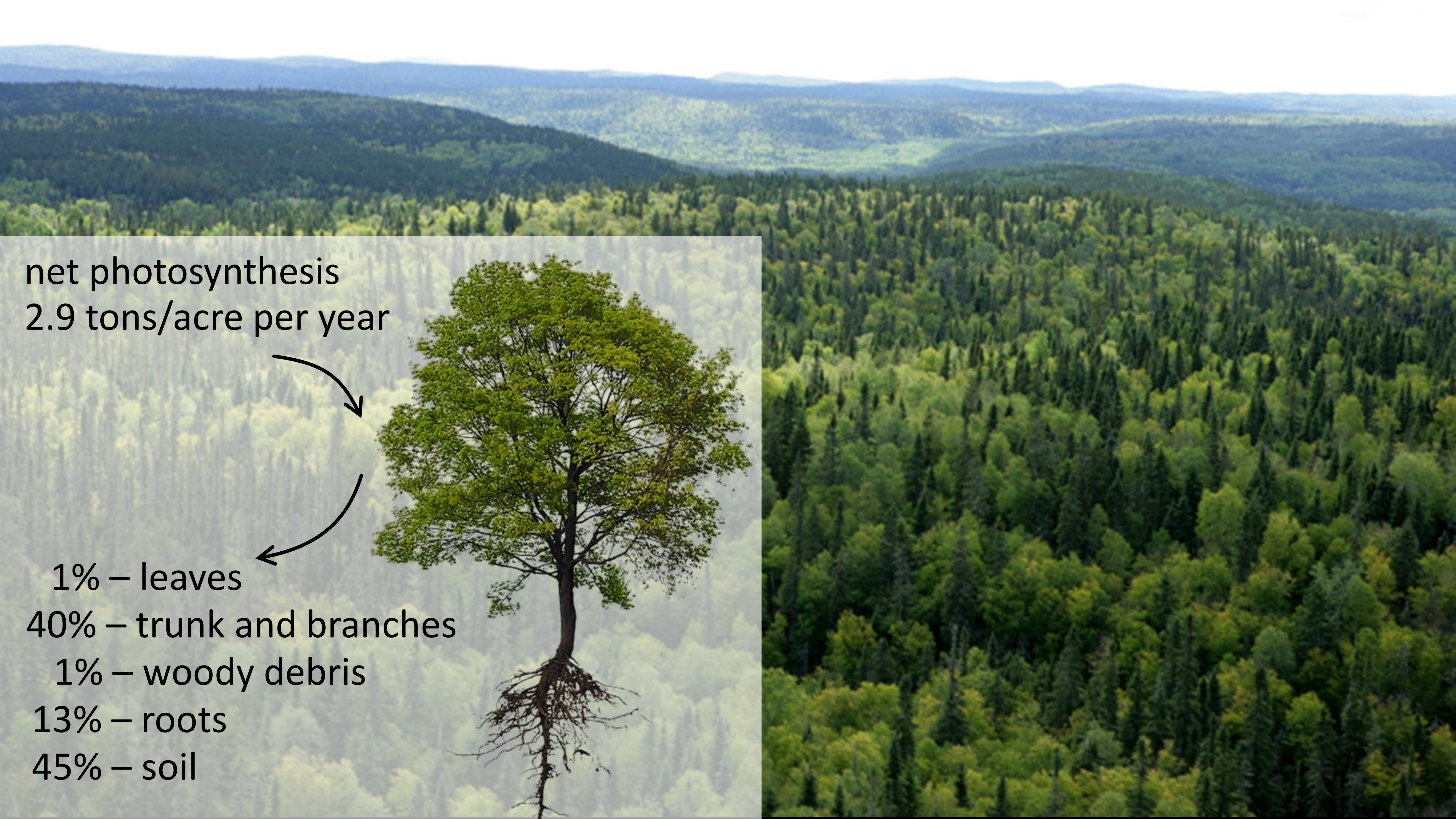
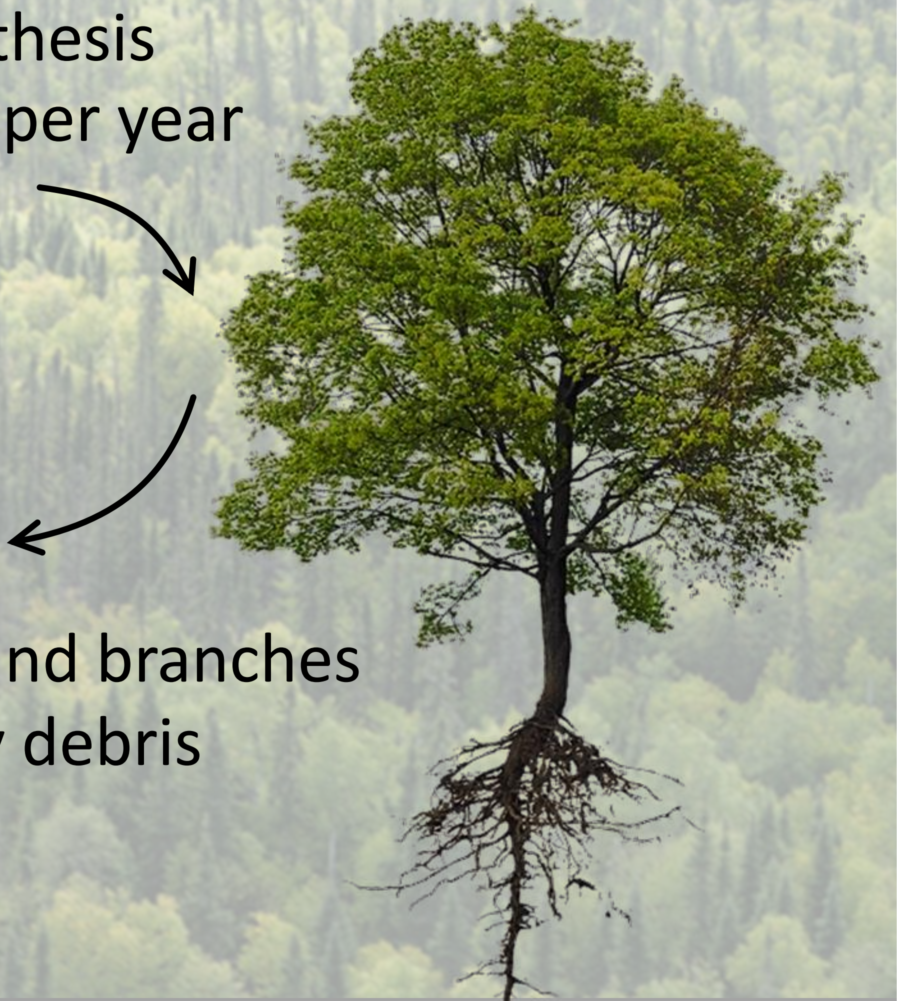


Fig. 1. Carbon sinks and sources (Pg C year^{-1}) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestation emissions.



net photosynthesis
2.9 tons/acre per year

1% – leaves
40% – trunk and branches
1% – woody debris
13% – roots
45% – soil



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(Boreal) forests:

- **ecosystem**
- **source for green economy**
- **carbon sink**

Trees assimilate atmospheric carbon and allocate it to growth and development.

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(Boreal) forests:

- **ecosystem**
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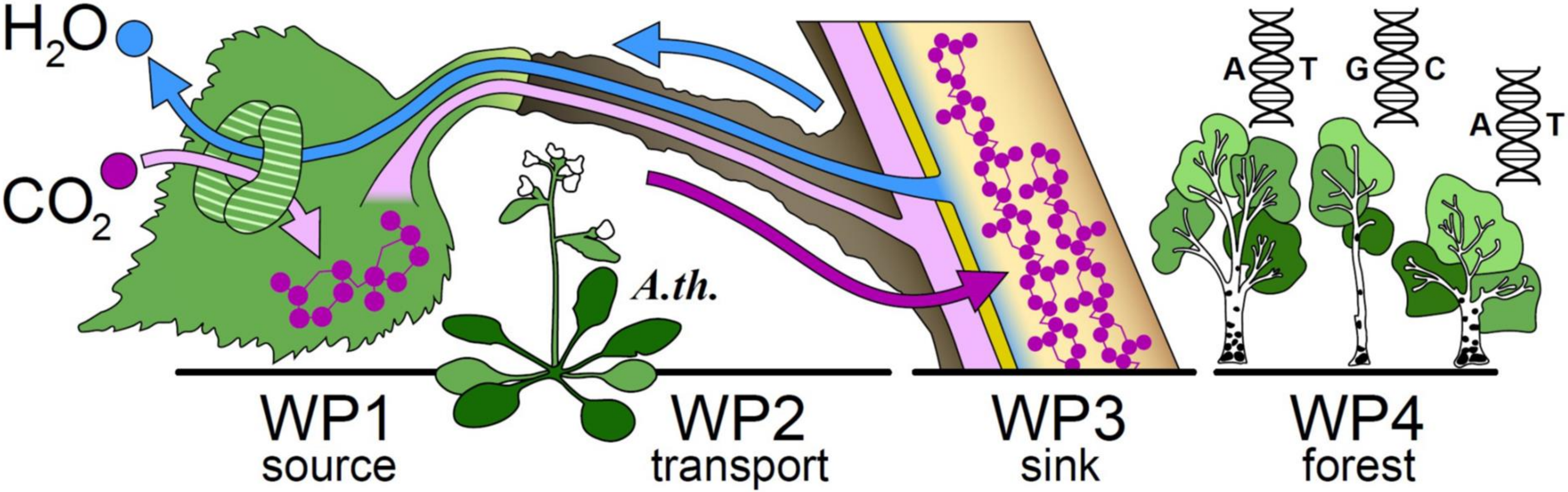
- **carbon sink**

Trees assimilate atmospheric carbon and allocate it to growth and development.

TreeBio CoE aims at understanding physiological and genetic basis of carbon sink effect.

TreeBio CoE: Understanding Carbon Sequestration



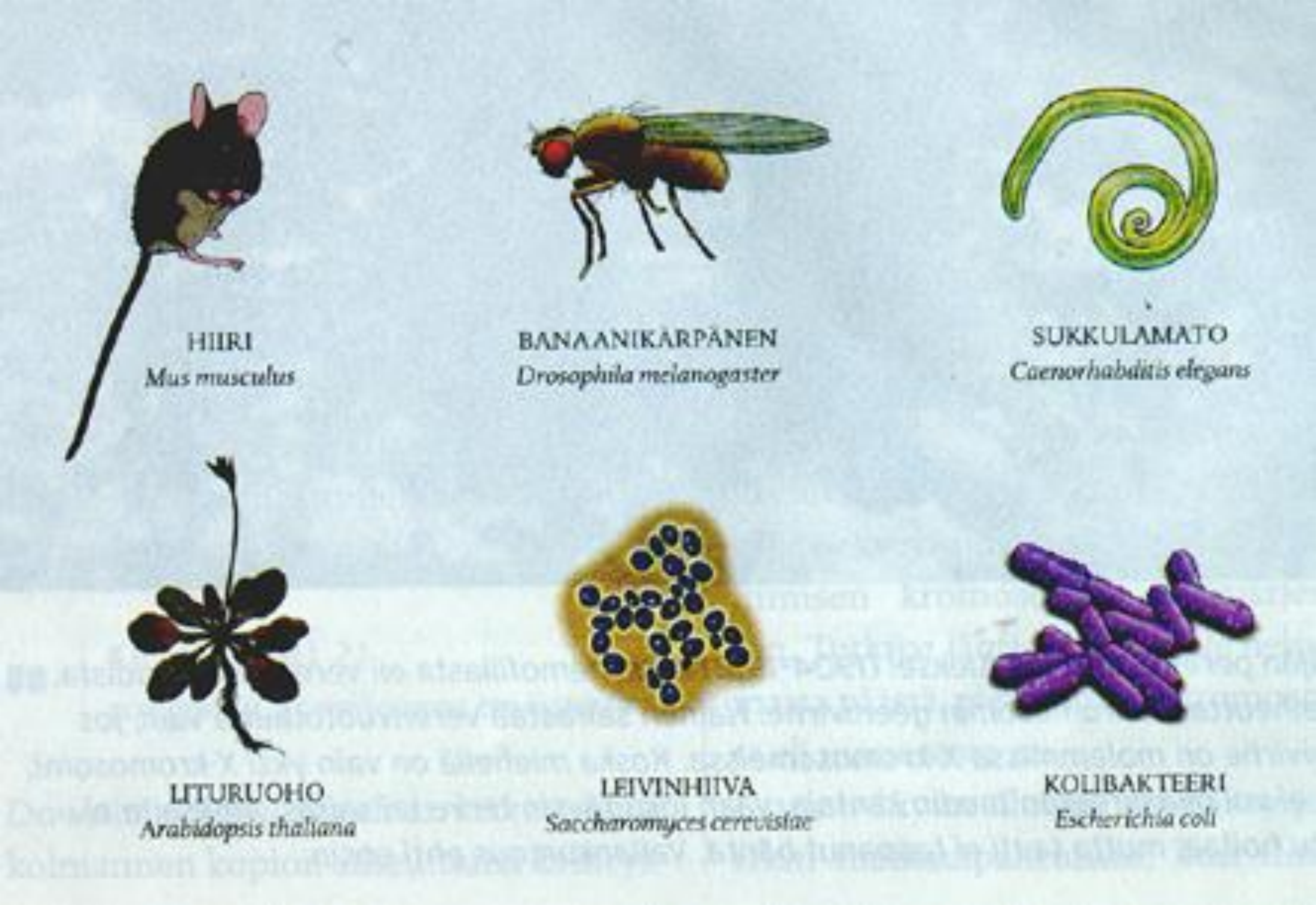
Role of stomatal regulation in obtaining CO_2

Development and function of the conductive tissues

Developmental regulation of carbon sequestration in wood

Natural variation and breeding of carbon assimilation in forest trees

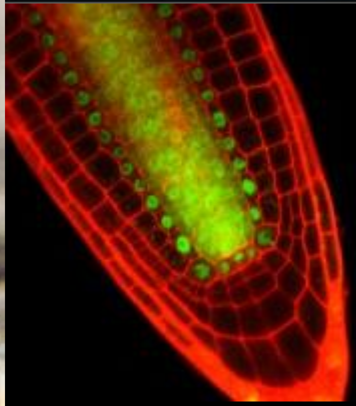
Arabidopsis is a plant model

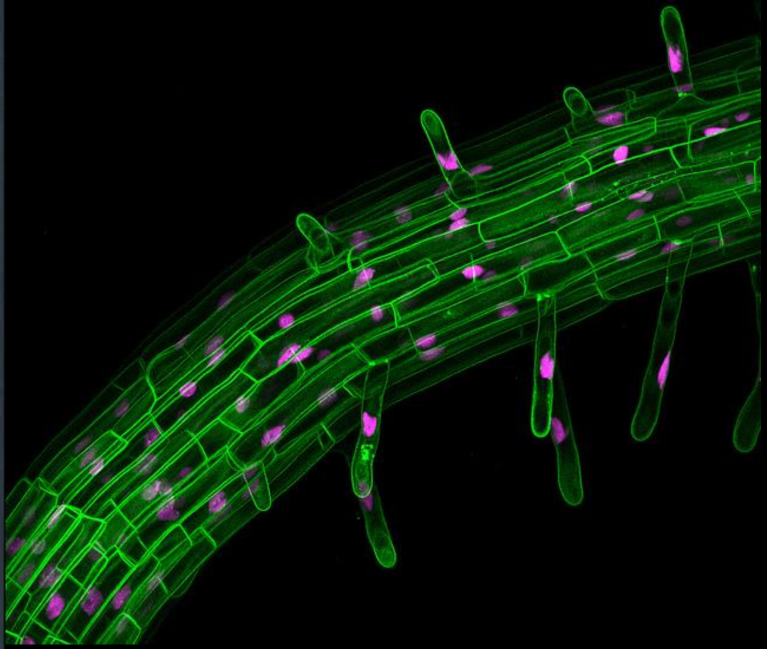


Arabidopsis thaliana
- “fruit fly of plant kingdom”

- Small genome (130 Mb), published yr 2000
- Short generation time, self-fertile
- Advanced classical genetics: many known mutations; easy to carry new screens
- Molecular genetic techniques well established (gene transfer)

Arabidopsis is a plant model





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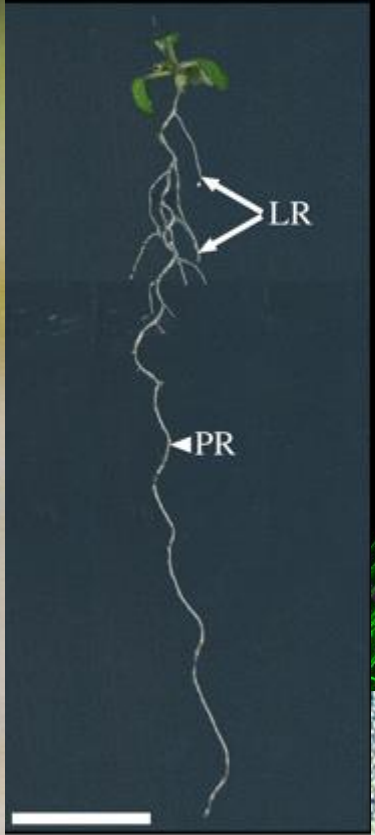
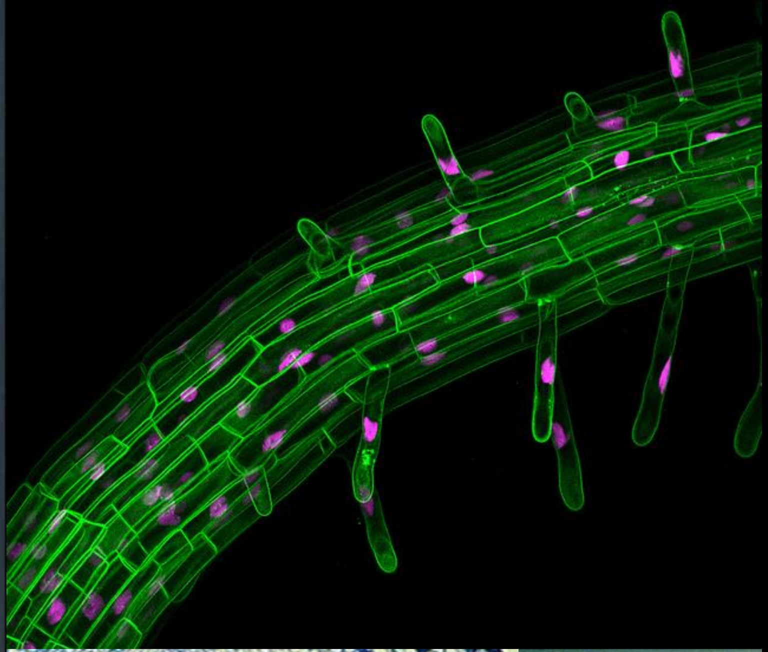
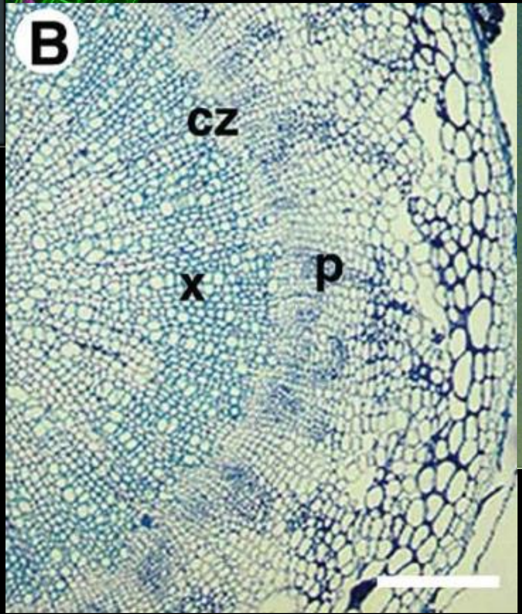
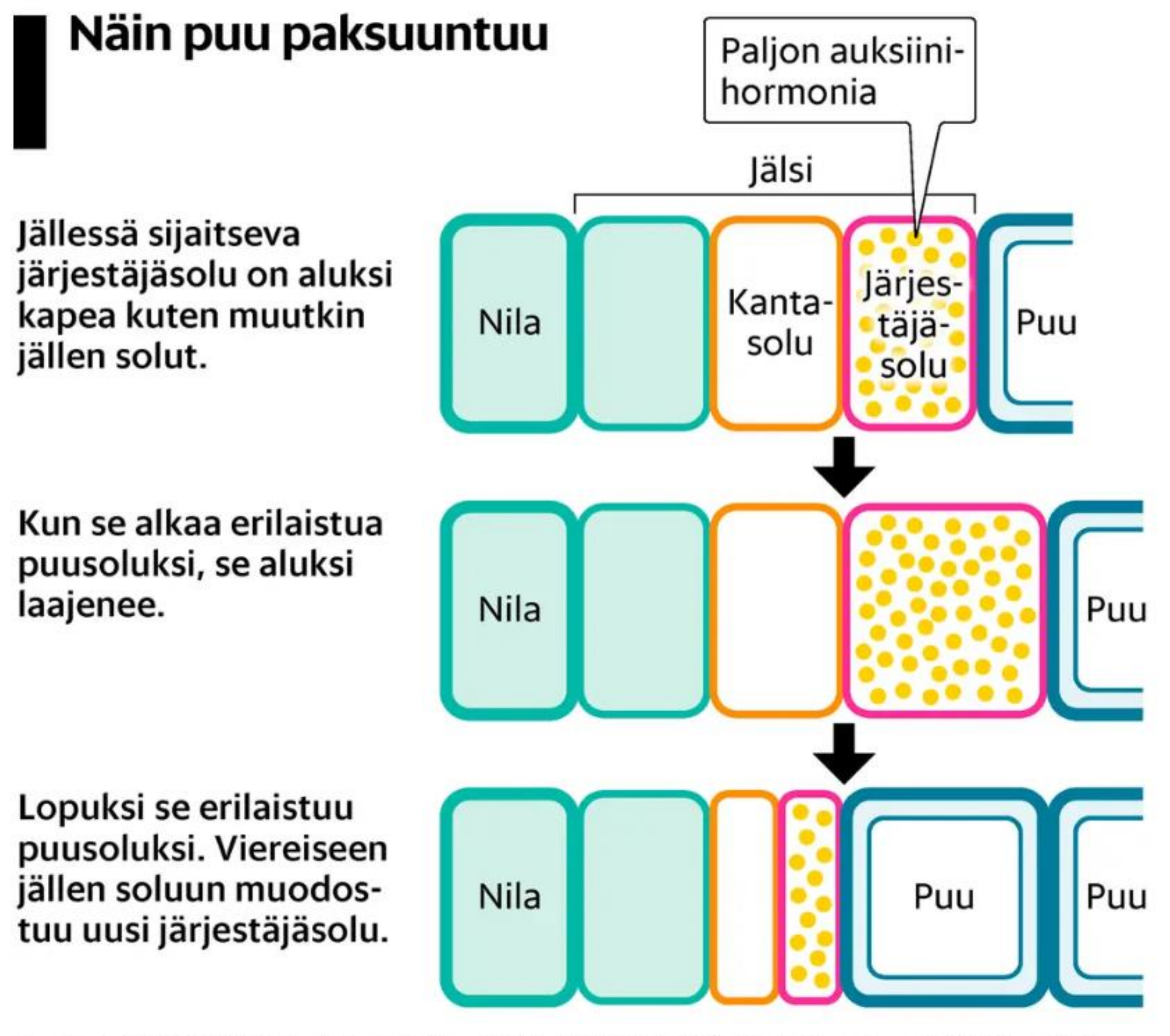






Miten ihmeessä puu kasvaa paksuutta jopa tuhat vuotta? Suomalaiset kasvitieteilijät ratkaisivat 150 vuotta vanhan arvoituksen



Näin puu paksuuntuu

Jällessä sijaitseva järjestäjäsolu on aluksi kapea kuten muutkin jällen solut.

Kun se alkaa erilaistua puusoluksi, se aluksi laajenee.

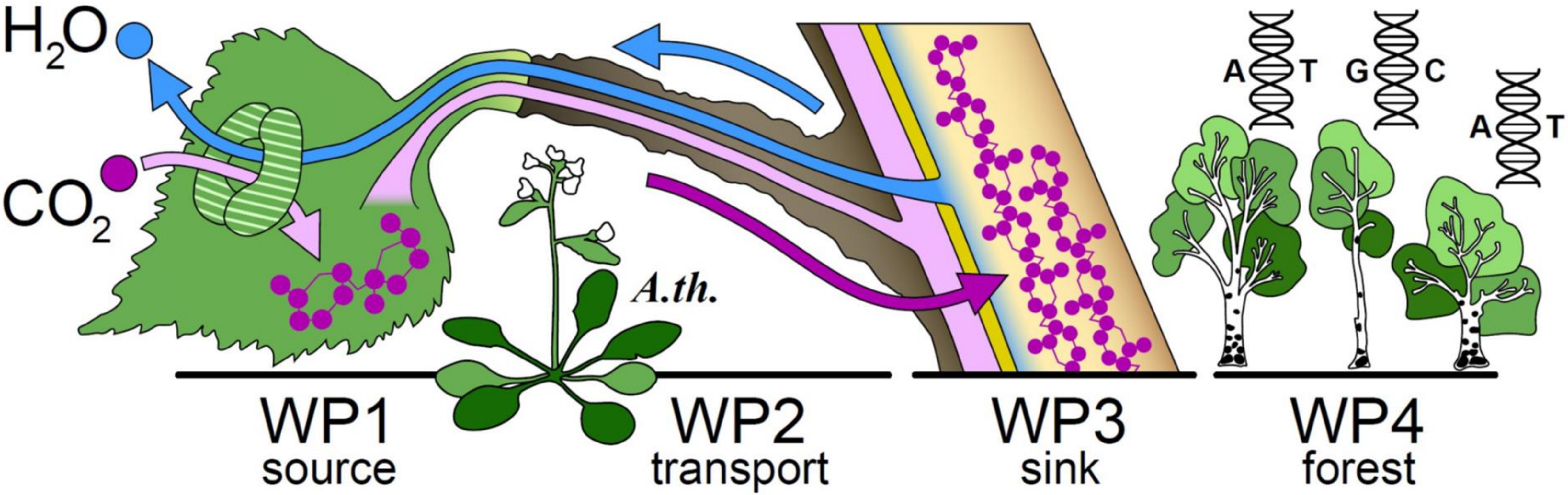
Lopuksi se erilaistuu puusoluksi. Viereiseen jällen soluun muodostuu uusi järjestäjäsolu.

Koonnut: ARJA KIVIPELTO / HS, grafiikka: JUKKA HIMANEN / HS, lähde: Smetana et al Nature 2019

Ari Pekka Mähönen

HS TIEDE

TreeBio CoE: Understanding Carbon Sequestration



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Birch (*Betula pendula*), emerging genetic model for (boreal) tree biology

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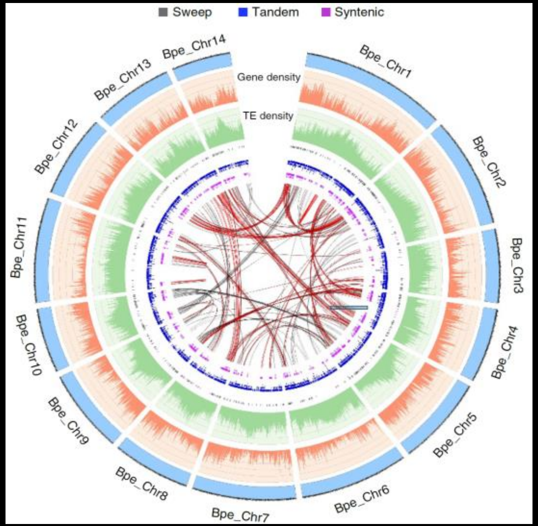


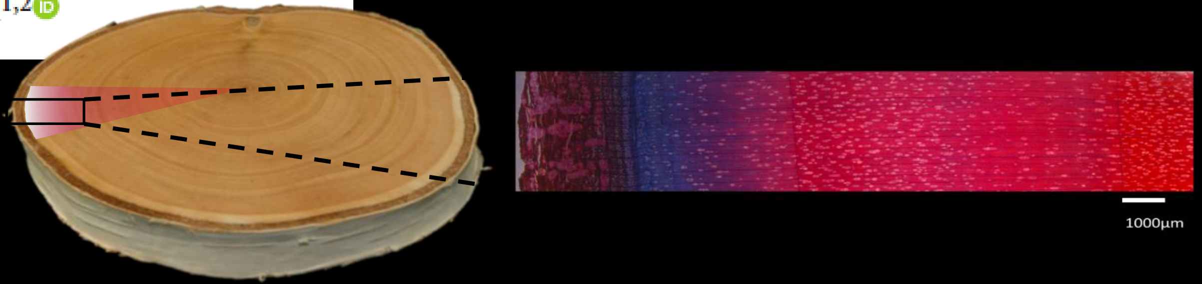
Salojärvi J, Smolander OP *et al.*
2017, *Nat Genetics*

- **Genome sequence**

nature genetics
OPEN

Genome sequencing and population genomic analyses provide insights into the adaptive landscape of silver birch

Jarkko Salojärvi[1,2,31], Olli-Pekka Smolander[3,31], Kaisa Nieminen[4], Sitaram Rajaraman[1,2], Omid Safronov[1,2], Pezhman Safdari[1,2], Airi Lamminmäki[1,2], Juha Immanen[1–3], Tianying Lan[5], Jaakko Tanskanen[2–4], Pasi Rastas[6,30], Ali Amiryousefi[1,2], Balamuralikrishna Jayaprakash[3,30], Juhana I Kammonen[3], Risto Hagqvist[7], Gugan Eswaran[1–3], Viivi Helena Ahonen[8,30], Juan Alonso Serra[1–3], Fred O Asiegbu[2,9], Juan de Dios Barajas-Lopez[10], Daniel Blande[8], Olga Blokhina[1], Tiina Blomster[1–3], Suvi Broholm[2,11,30], Mikael Brosché[1,2,12], Fuqiang Cui[1,2,30], Chris Dardick[13], Sanna E Ehonen[1,2], Paula Elomaa[2,11], Sacha Escamez[14], Kurt V Fagerstedt[1,2], Hiroaki Fujii[10], Adrien Gauthier[1,2,30], Peter J Gollan[10], Pauliina Halimaa[8], Pekka I Heino[2,15], Kristiina Himanen[2,11], Courtney Hollender[13], Saijaliisa Kangasjärvi[10], Leila Kauppinen[16], Colin T Kelleher[17], Sari Kontunen-Soppela[18], J Patrik Koskinen[3,30], Andriy Kovalchuk[2,9], Sirpa O Kärenlampi[8], Anna K Kärkönen[2,11,30], Kean-Jin Lim[2,11], Johanna Leppälä[1,2], Lee Macpherson[19], Juha Mikola[20], Katriina Mouhu[2,11], Ari Pekka Mähönen[1–3], Ülo Niinemets[21], Elina Oksanen[18], Kirk Overmyer[1,2], E Tapio Palva[2,15], Leila Pazouki[21], Ville Pennanen[2,15], Tuula Puhakainen[15,30], Péter Poczai[22], Boy J H M Possen[23,30], Matleena Punkkinen[10], Moona M Rahikainen[10], Matti Rousi[23], Raili Ruonala[3,30], Christiaan van der Schoot[24], Alexey Shapiguzov[1,2,25], Maija Sierla[1,2], Timo P Sipilä[1,2], Suvi Sutela[26], Teemu H Teeri[2,11], Arja I Tervahauta[8], Aleksia Vaattovaara[1,2], Jorma Vahala[1,2], Lidia Vetchinnikova[27], Annikki Welling[1,30], Michael Wrzaczek[1,2], Enjun Xu[1,2,30], Lars G Paulin[3], Alan H Schulman[2–4], Martin Lascoux[28], Victor A Albert[5], Petri Auvinen[3], Ykä Helariutta[1–3,29] & Jaakko Kangasjärvi[1,2]



ARTICLE

OPEN

doi:10.1038/nature12211

The Norway spruce genome sequence and conifer genome evolution

Picea abies: A Very Large Genome

- 20 Gb, **nearly 7x human**
  - typical for conifers
- Little known about gene and genome structure
- Only ~0.1 % consists of genes
- Largest genome sequenced so far
- Other ongoing conifer sequencing projects
  - *Picea glauca* (Canada)
  - *Pinus taeda* (US)

Arabidopsis
(120 Mbp)

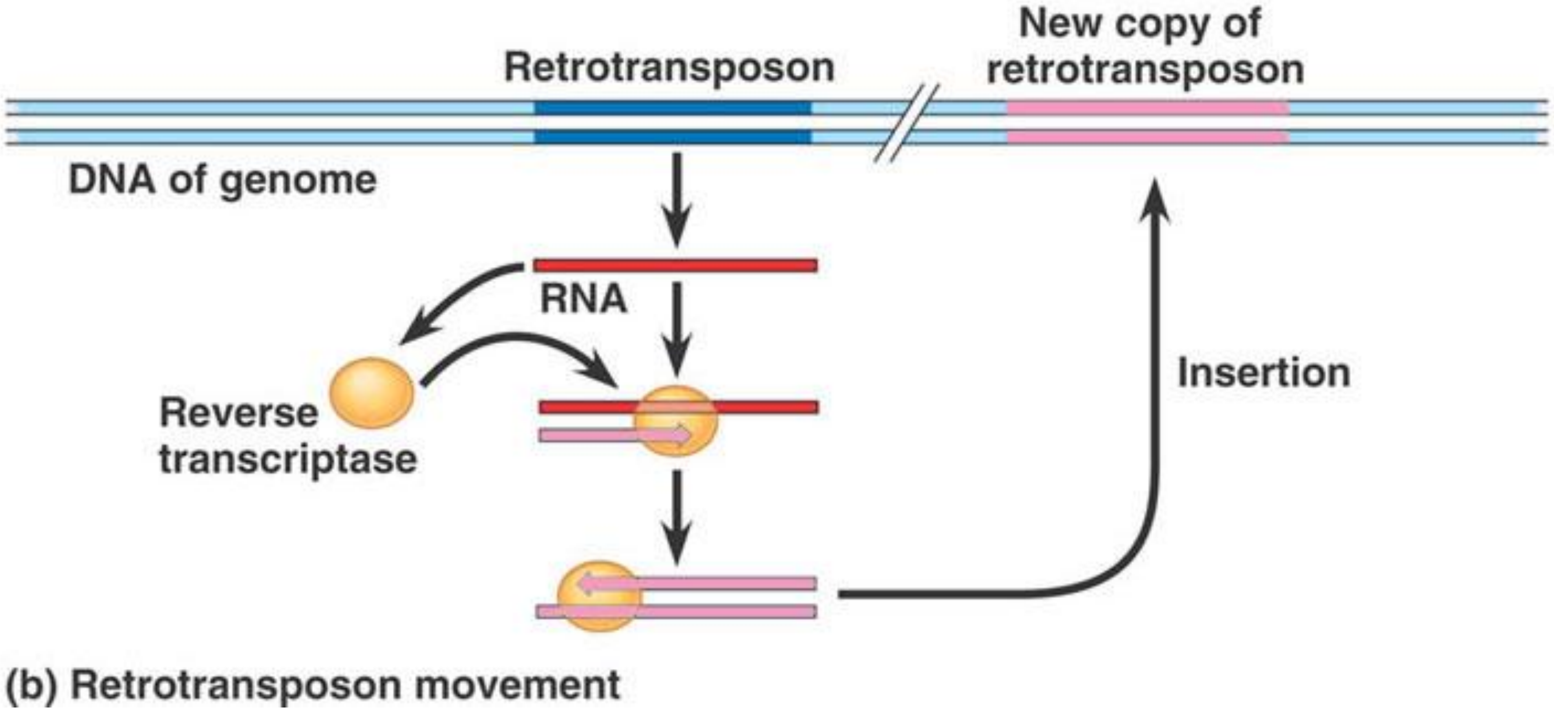
Poplar
(450 Mbp)

Humans
(3 000 Mbp)

Norway spruce
(20 000 Mbp)

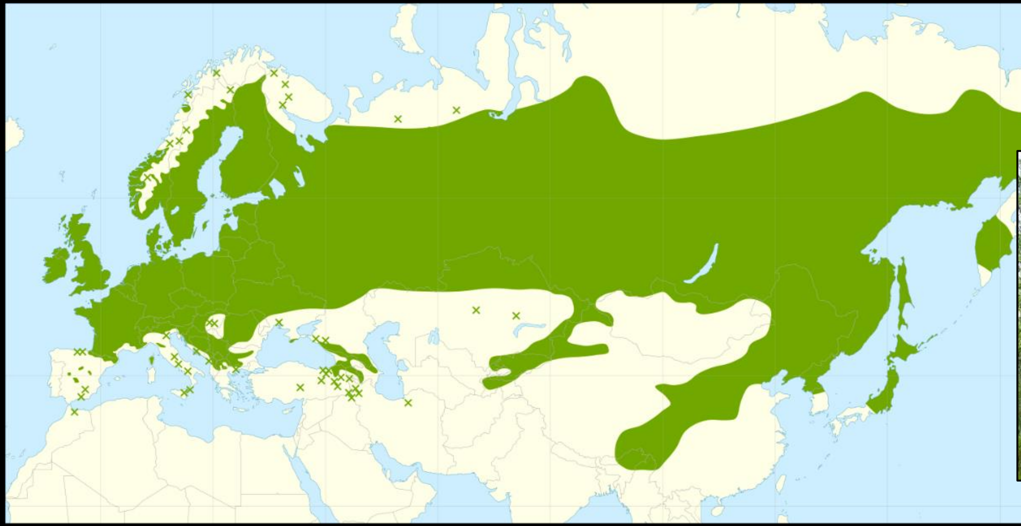
Hyppivät geenit ovat paisuttaneet kuusen genomin 7x ihmisen genomin (40x koivun genomin) kokoiseksi

Barbara McClintock



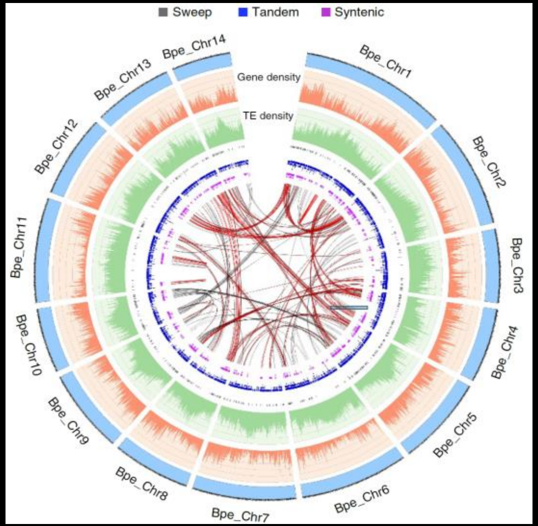
(b) Retrotransposon movement

Birch (*Betula pendula*), emerging genetic model for (boreal) tree biology



- **Wide distribution, variable, resilient, borderline tree**

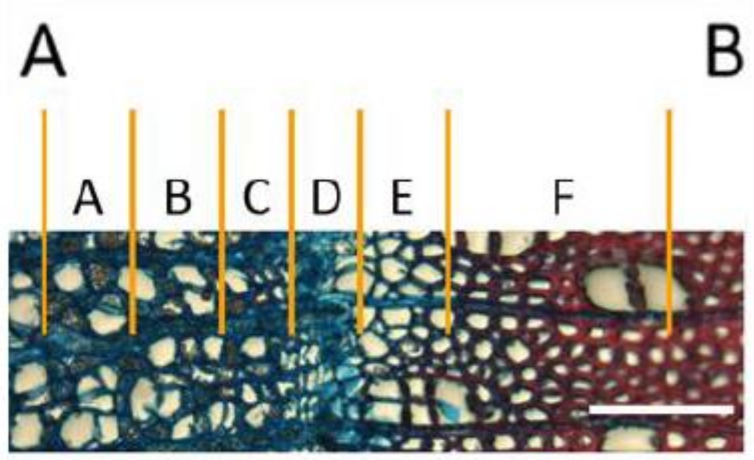
Salojärvi J, Smolander OP *et al.*
2017, *Nat Genetics*

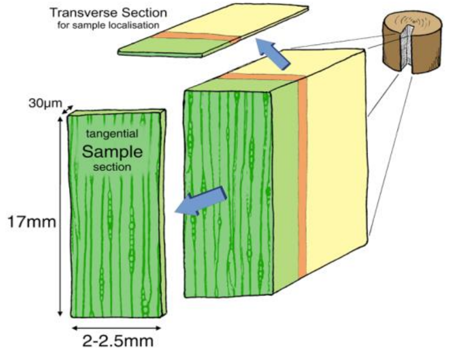


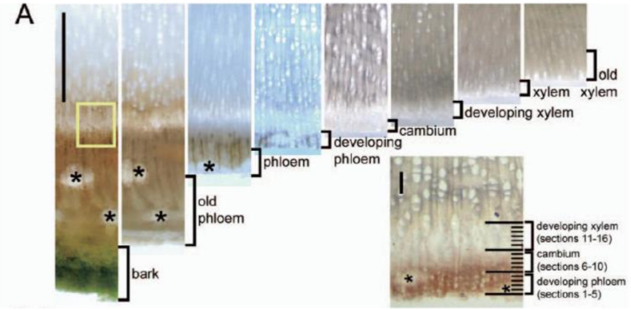
- **Genome sequence**

Diversity in birch wood

Cytokinin gradient in cambium is broader than auxin gradient and peaks in phloem/cambium

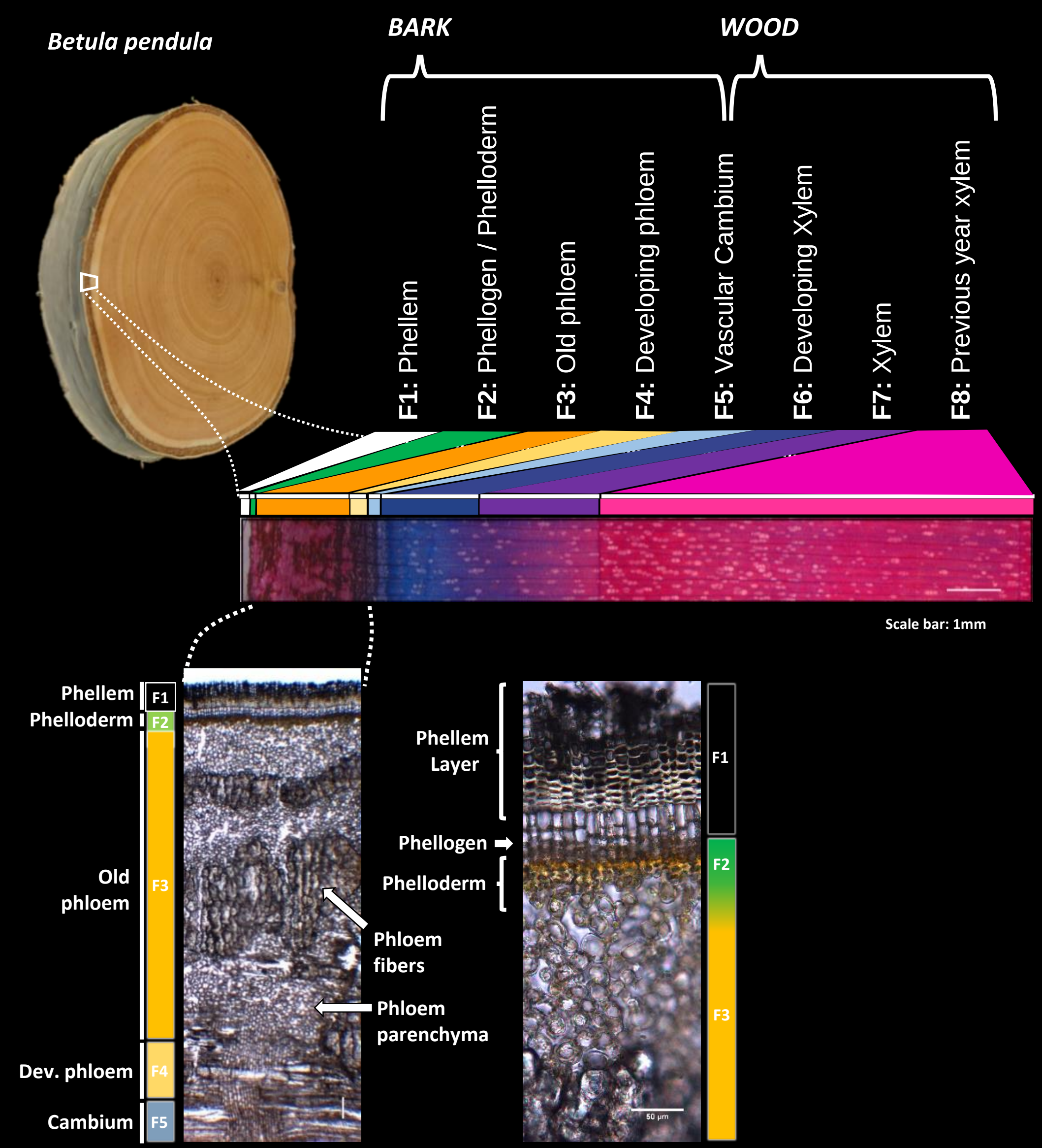






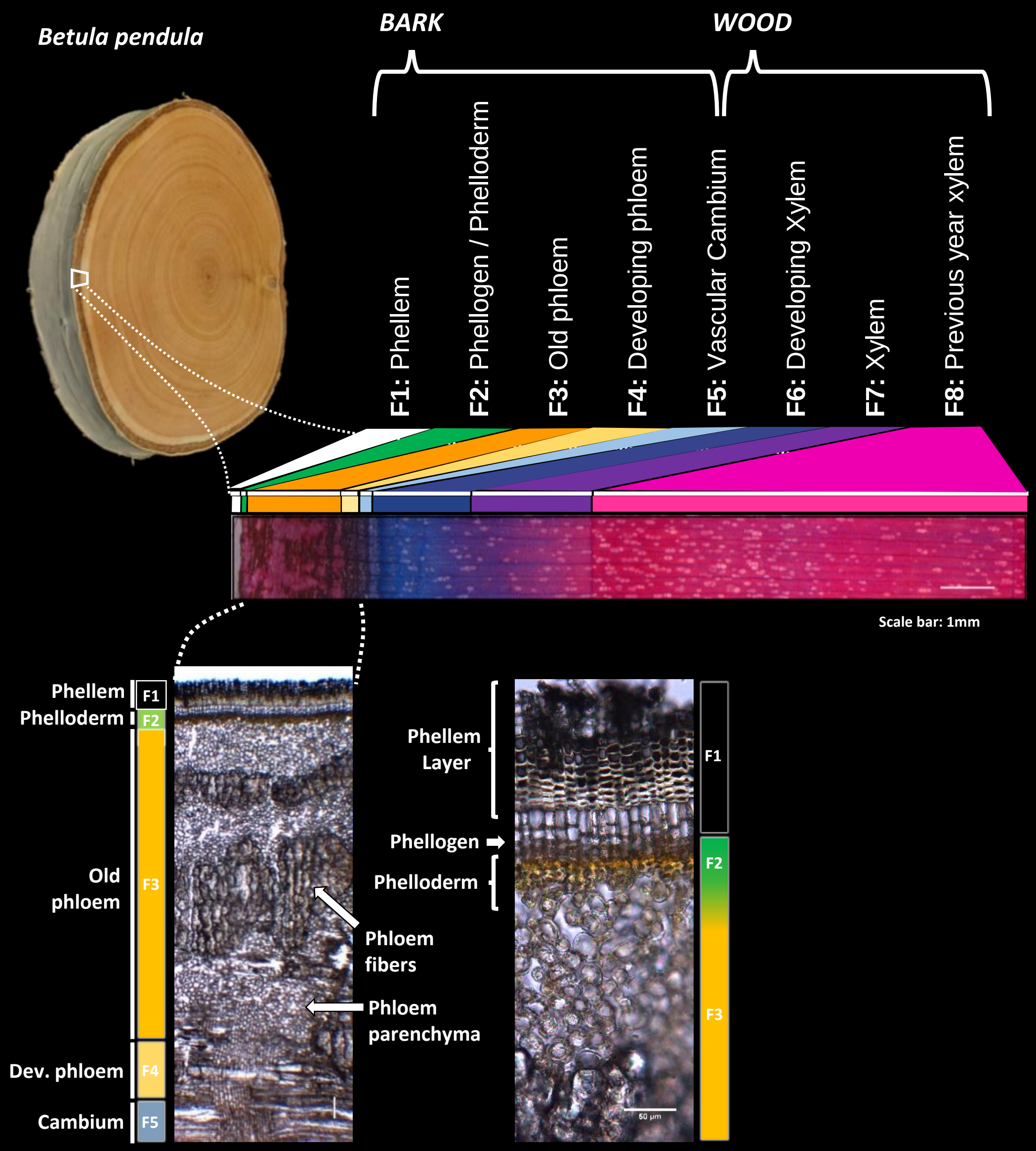
Immanen, Nieminen et al. (2016) Current Biology

Comparative dissection of stem fractions.

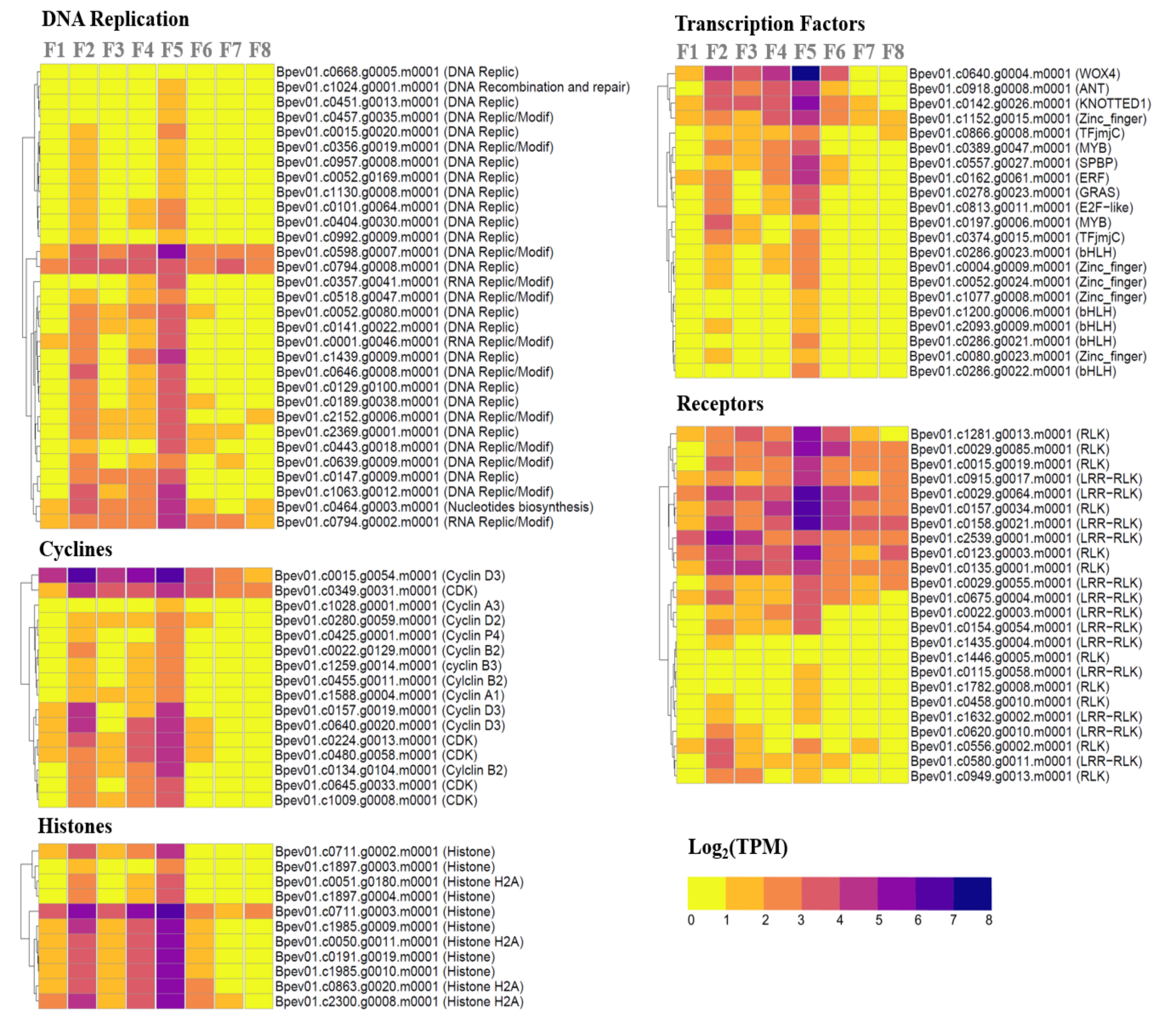


Betula pendula

Comparative dissection of stem fractions.



Betula pendula

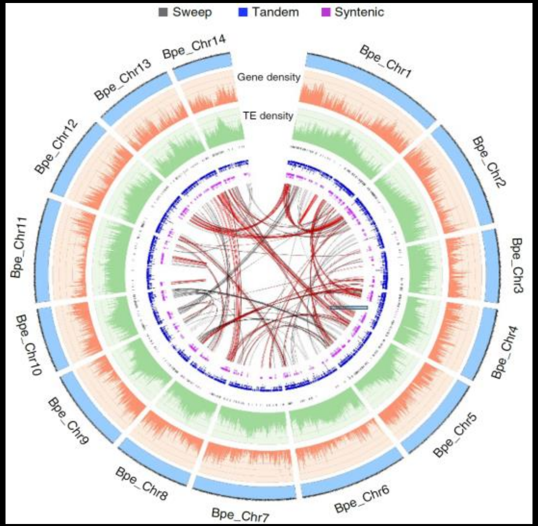


Juan Alonso Serra, Omid Safranov et al. (2020) New Phytologist

Birch (*Betula pendula*), emerging genetic model for (boreal) tree biology

- **Wide distribution, variable, resilient, borderline tree**

Salojärvi J, Smolander OP *et al.*
2017, *Nat Genetics*



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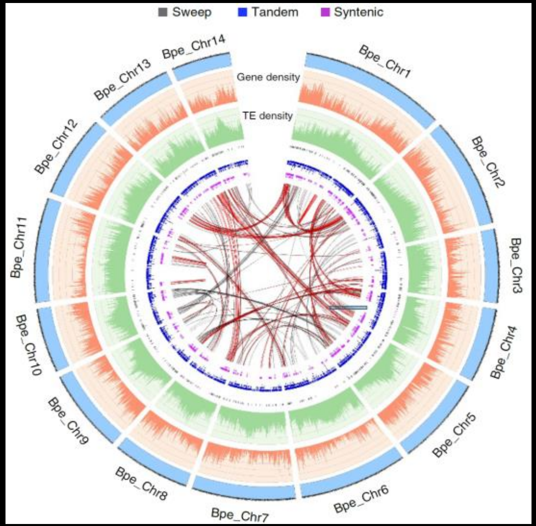

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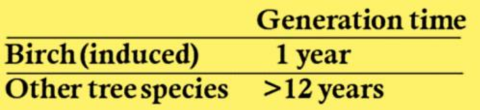
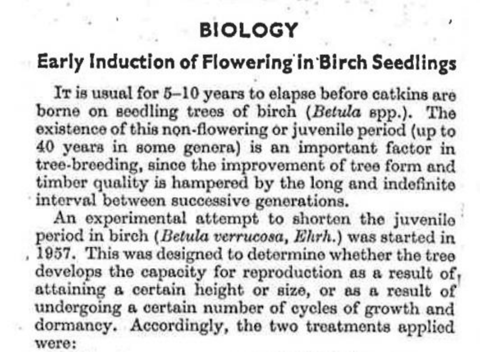


	Generation time
Birch (induced)	1 year
Other tree species	>12 years



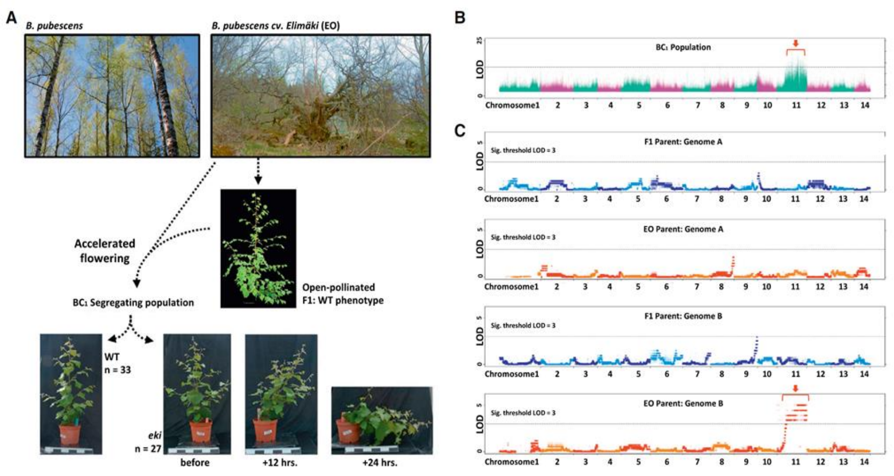
BIOLOGY

Early Induction of Flowering in Birch Seedlings

It is usual for 5–10 years to elapse before catkins are borne on seedling trees of birch (*Betula* spp.). The existence of this non-flowering or juvenile period (up to 40 years in some genera) is an important factor in tree-breeding, since the improvement of tree form and timber quality is hampered by the long and indefinite interval between successive generations.

An experimental attempt to shorten the juvenile period in birch (*Betula verrucosa*, *Ehrh.*) was started in 1957. This was designed to determine whether the tree develops the capacity for reproduction as a result of attaining a certain height or size, or as a result of undergoing a certain number of cycles of growth and dormancy. Accordingly, the two treatments applied were:

Longman & Wareing 1959, *Nature*

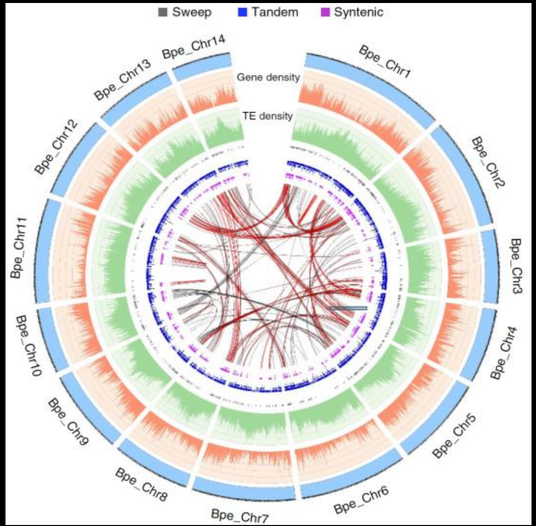


Alonso Serra *et al.* 2020, *Curr Biol.*

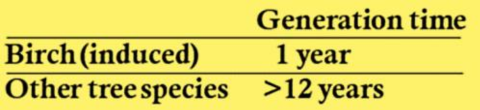
- **Accelerated flowering allows genetic analysis**

Birch (*Betula pendula*), emerging genetic model for (boreal) tree biology

Salojärvi J, Smolander OP *et al.* 2017, *Nat Genetics*



- **Wide distribution, variable, resilient, borderline tree**
- **Genome sequence**



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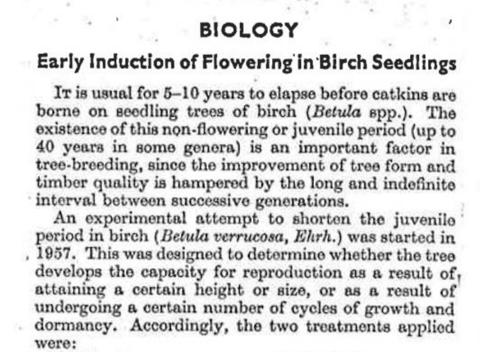

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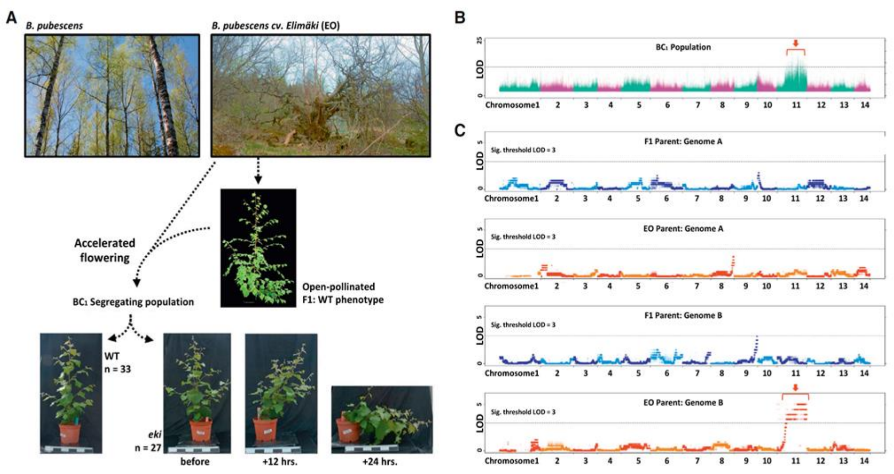


Alonso Serra *et al.* 2020, *Curr Biol.*

- **Accelerated flowering allows genetic analysis**

- **Proof-of-concept in gene identification**

Birch as a genetic model for tree architecture

Alonso Serra et al. 2020 Curr Biol; Chang et al. (2023) PNAS

TREE ARCHITECTURE IN BIRCH MANISFESTS DIVERSITY AND ADAPTATIONS

WT

Pendula

Youngii

Kiilopää

B. PENDULA ´YOUNGII´ - MONOGENIC RECESSIVE MUTATION

Branch development doesn´t respond normally to gravity

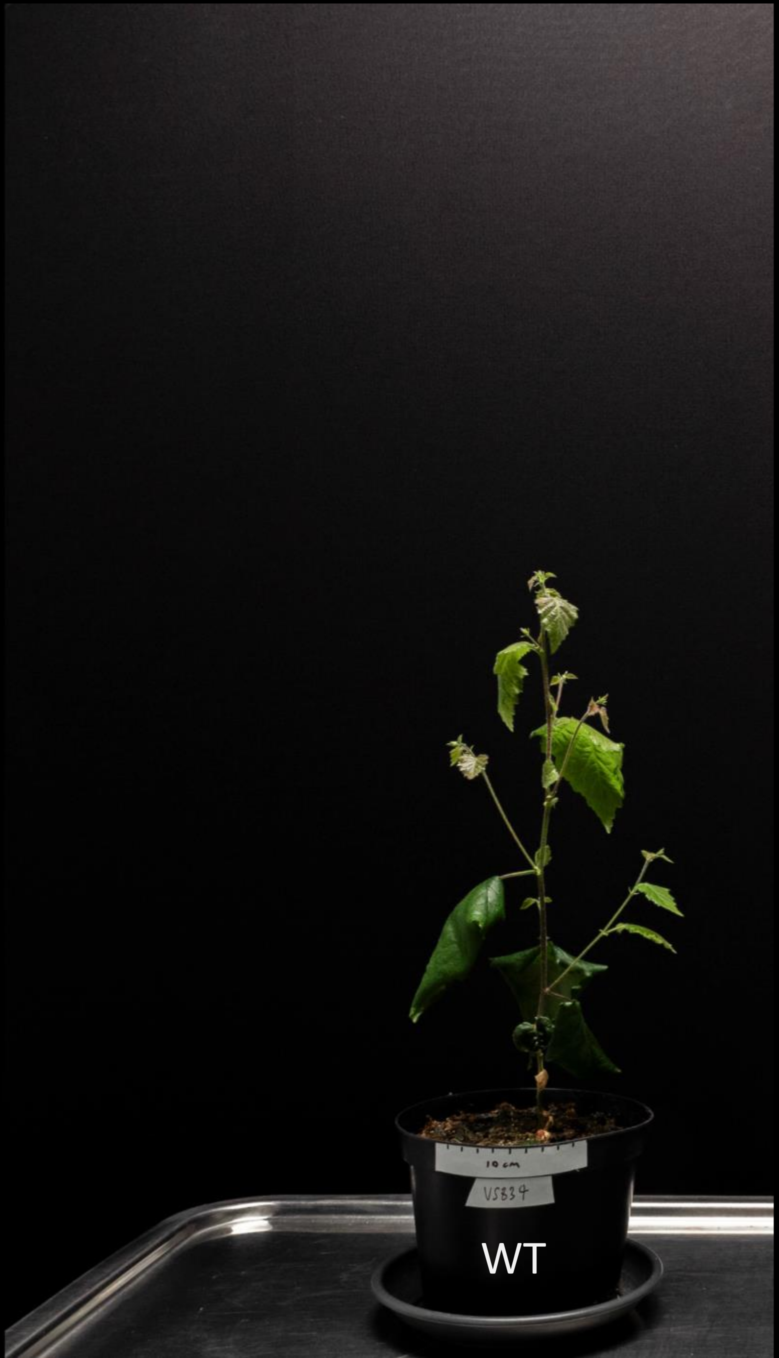
Xueping Shi

B. pendula ´Youngii`

F1: 100% WT

BC1: 50% WT 50% Mutant

WT VS. LAZY1 RNAi (16 DAYS – 24/7 LIGHTS)

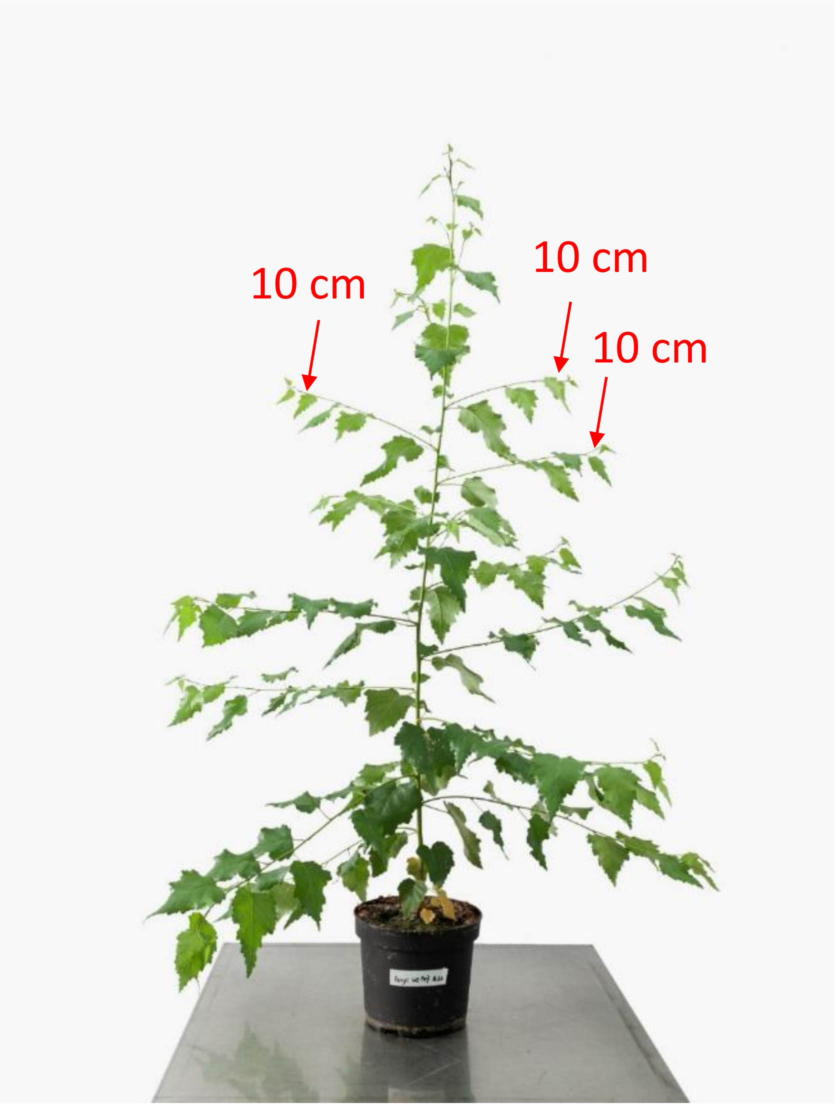


Sampo
Muranen

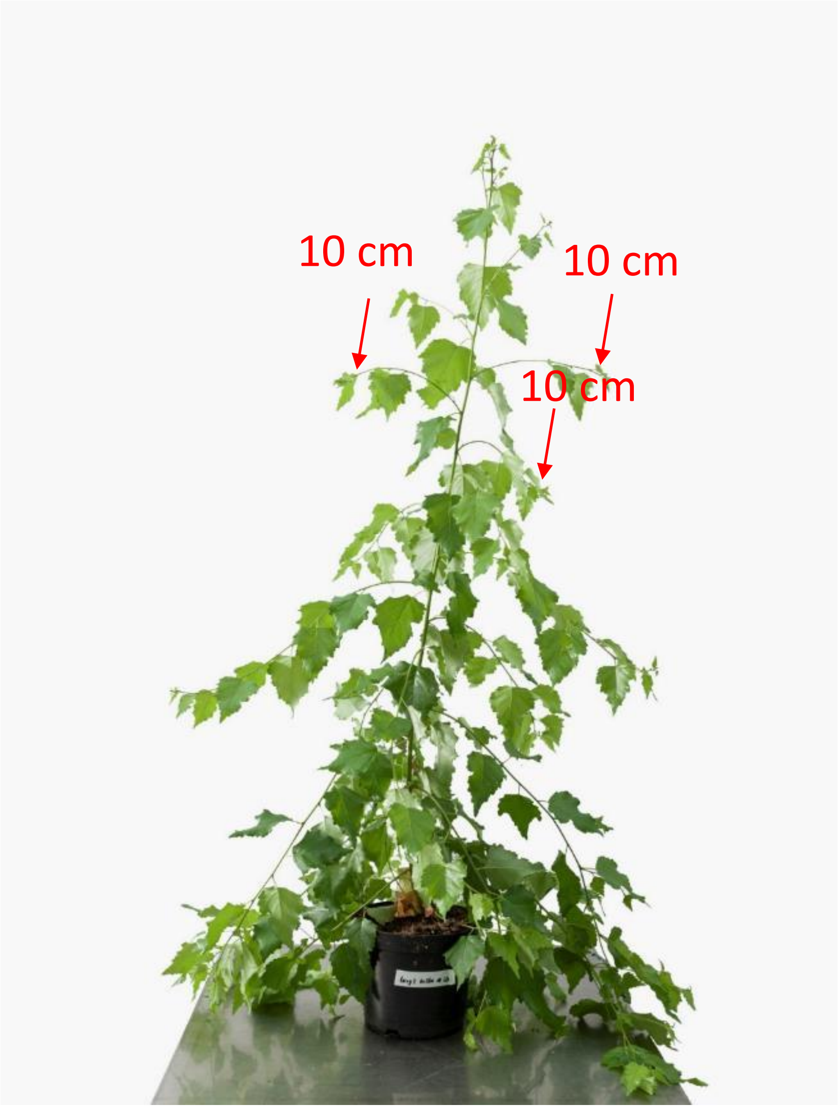
V5834 VS. LAZY1 RNAi (16 DAYS – 24/7 LIGHTS)

Sampo
Muranen

LAZY1 SEG. POP. RNA-SEQ FROM UPPER AND LOWER SIDES OF BRANCH TIPS (2021)

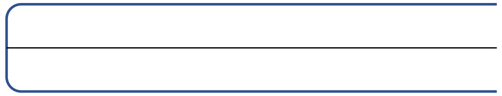


3 BRANCH TIPS SAMPLED (3 WT)



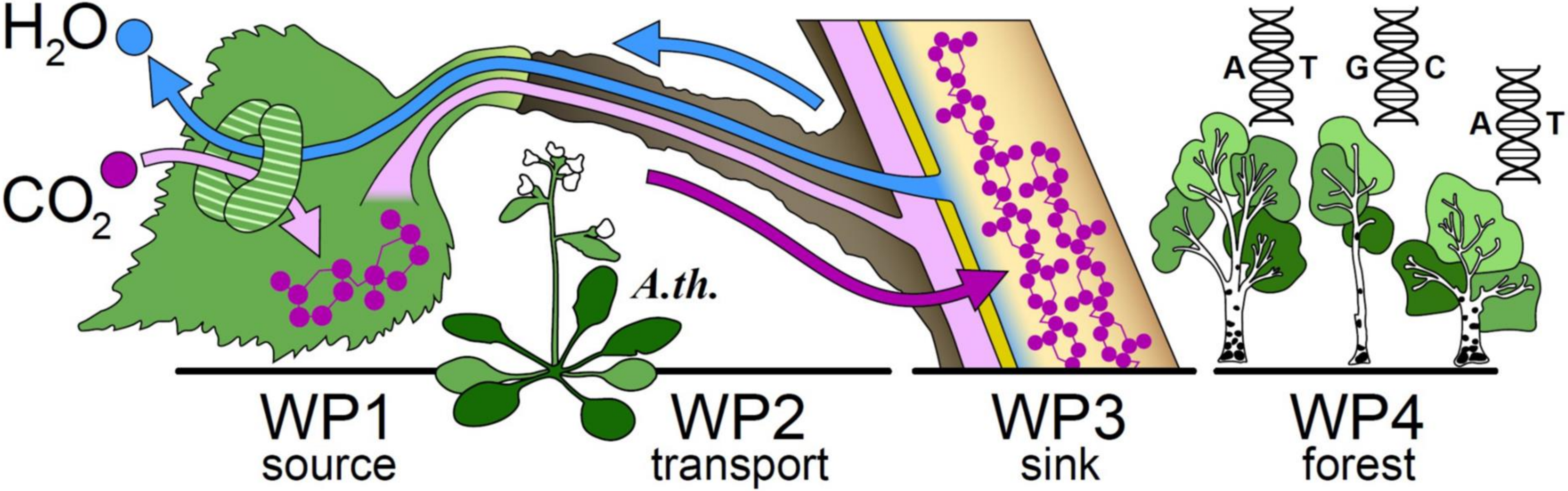
3 BRANCH TIPS SAMPLED (3 M)

Upper side



Lower side

TreeBio CoE: Understanding Carbon Sequestration



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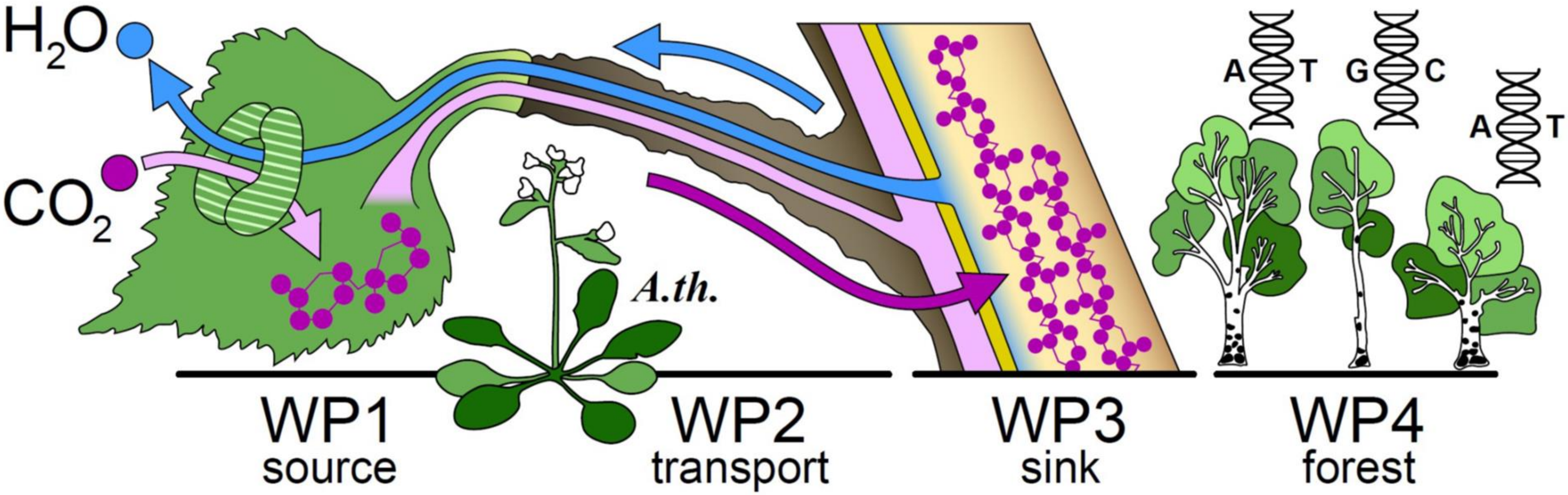
ARABIDOPSIS WT VS LAZY1 MUTANT TIME-LAPSE

Koivututkimus paljasti kasvikunnalle tyypillisen oksien polaarisuuden.

Tällä hetkellä tutkimme miten tämä polaarisuus määrittää puun laatuominaisuuksia.

TreeBio CoE: Understanding Carbon Sequestration



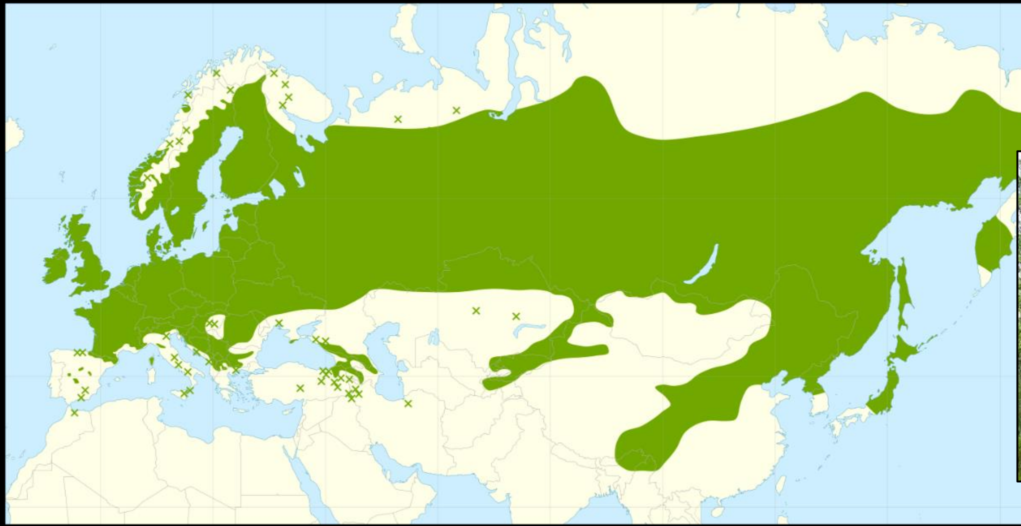
Role of stomatal regulation in obtaining CO_2

Development and function of the conductive tissues

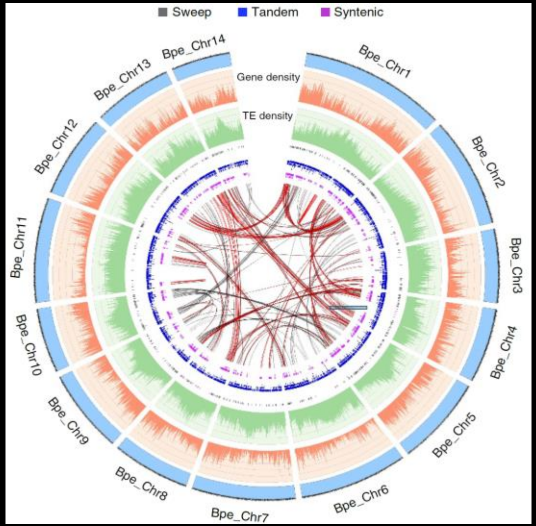
Developmental regulation of carbon sequestration in wood

Natural variation and breeding of carbon assimilation in forest trees

Birch (*Betula pendula*), emerging genetic model for (boreal) tree biology



- **Wide distribution, variable, resilient, borderline tree**



Salojärvi J, Smolander OP *et al.*
2017, *Nat Genetics*

- **Genome sequence**

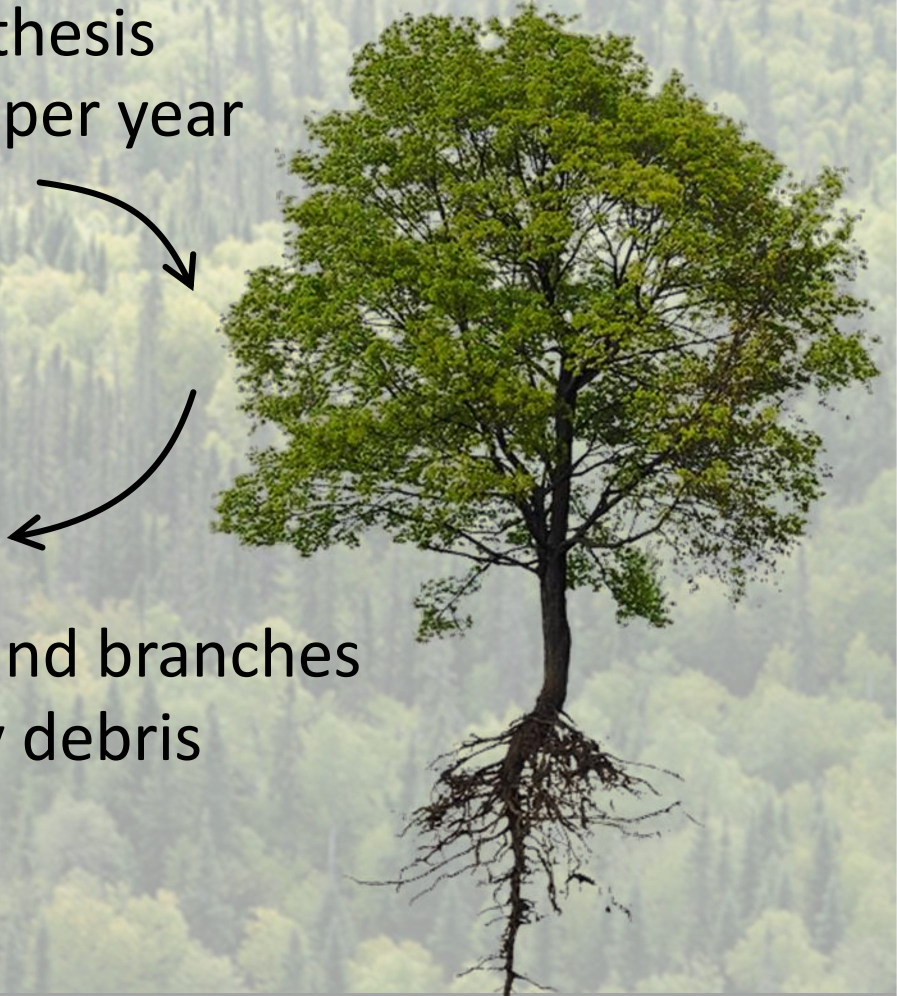
TREE ARCHITECTURE IN BIRCH MANISFESTS DIVERSITY AND ADAPTATIONS

WT

Pendula

Youngii

Kiilopää



net photosynthesis
2.9 tons/acre per year

1% – leaves
40% – trunk and branches
1% – woody debris
13% – roots
45% – soil

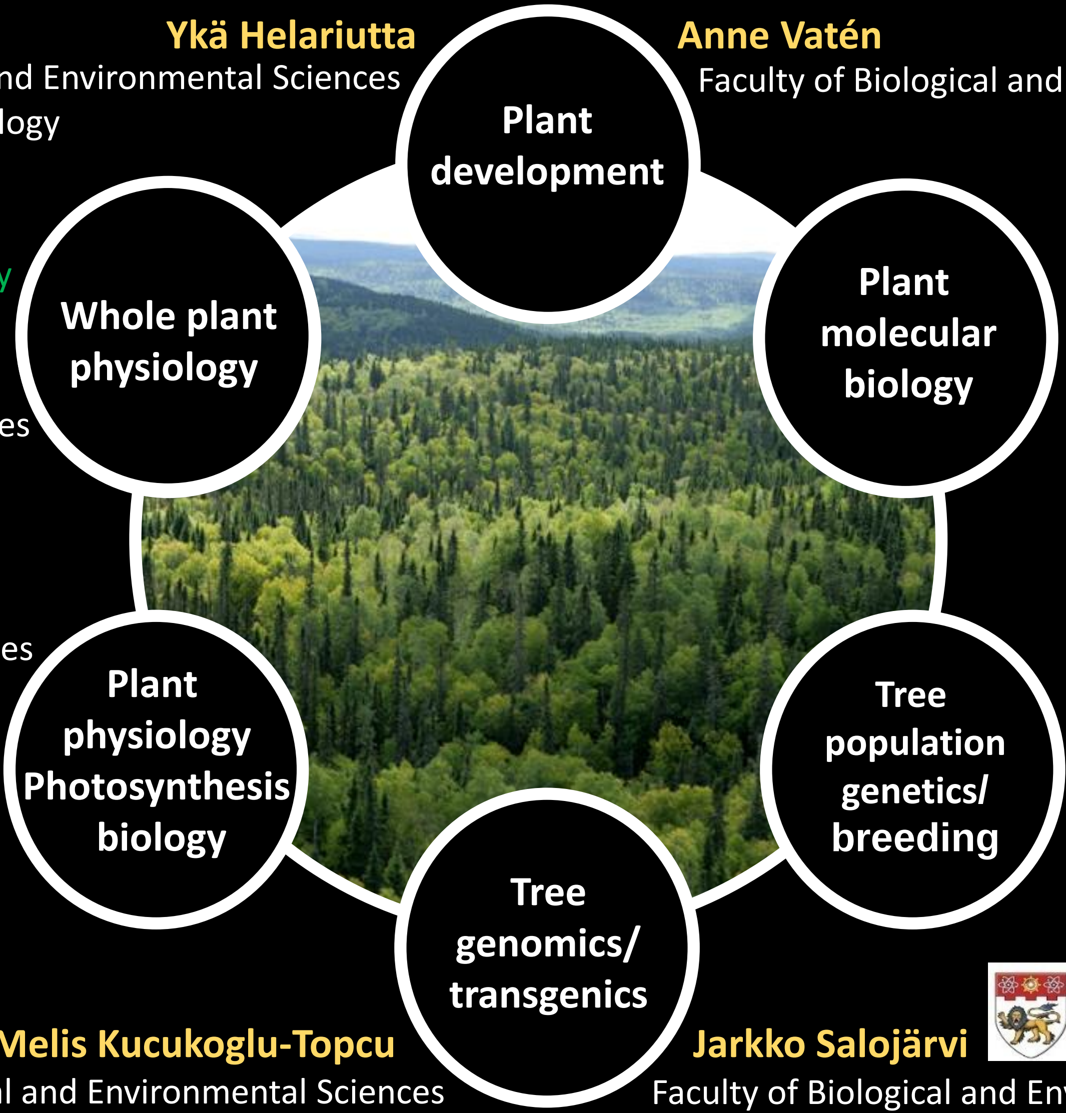
(Boreal) forests:

- **ecosystem**
- **source for green economy**
- **carbon sink**

Trees assimilate atmospheric carbon and allocate it to growth and development.

TreeBio CoE aims at understanding physiological and genetic basis of carbon sink effect.

Centre of Excellence of Tree Biology (2022-29), Academy of Finland



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Betula pendula ´Paimio´

TREEBIO CENTRE OF EXCELLENCE IN TREE BIOLOGY

HELSINGIN YLIOPISTO

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