

Taimede mälu: mis kasu on mäletamisest ja kas teinekord oleks parem unustada?

Ülo Niinemets,
Taimekasvatuse ja taimebioloogia õppetool,
Põllumajandus- ja keskkonnainstituut, Eesti Maaülikool

Õpilaste teadusseminar, 18. august, 2022, Viitna



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ÜLO NIINEMETS
Tartu 5. Keskkool
10.b klass

Botaanika sektsioon
Juhendaja Kalevi Kull
ENSV TA Zooloogia ja Botaanika Instituut

Produktionsbiologisches Institut an der Universität



ELSEVIER

Forest Ecology and Management 70 (1994) 1–10

Forest Ecology
and
Management

Leaf weight per area and leaf size of 85 Estonian woody species in relation to shade tolerance and light availability

Ülo Niinemets^{a,*}, Kalevi Kull^b

^a*Institute of Ecology, Estonian Academy of Sciences, Lai 40, EE-2400 Tartu, Estonia*

^b*Institute of Zoology and Botany, Estonian Academy of Sciences, Vanemuise 21, EE-2400 Tartu, Estonia*

Accepted 13 July 1994

	0,9	30,5	33,1
Amelanchier	0,2	15,5	16,7
spicata	0,7	20,3	30,4

Estonia's research revival

*How joining the EU helped a small
nation to find strength in science.*

BY QUIRIN SCHIERMEIER

When Ülo Niinemets began his PhD in plant science at the University of Tartu in Estonia, he had access to only the most basic tools. It was 1993, two years after Estonia had won independence from the collapsing Soviet Union. The university had just two computers for around 10,000 students and researchers. “I had a ruler and a lab balance,” Niinemets says. “And that was basically it.”

Meie töörühma peamine huvi on mõista, kuidas taimed kohanevad keskkonnatingimustega

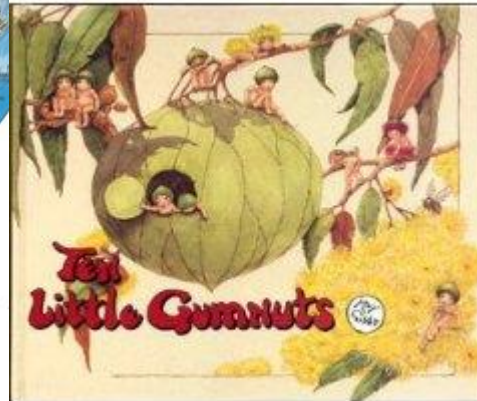


Praegused peamised uurimissuunad:

Taimede süsinikusidumise globaalne varieeruvus ja stressile kohanemine ja kohastumine

Taimede stress ja stressisignaalid (kuidas muutub taimede lõhn stressi korral)





Loengukava

Stress ja taimed. Kohanemine ja stressimälu

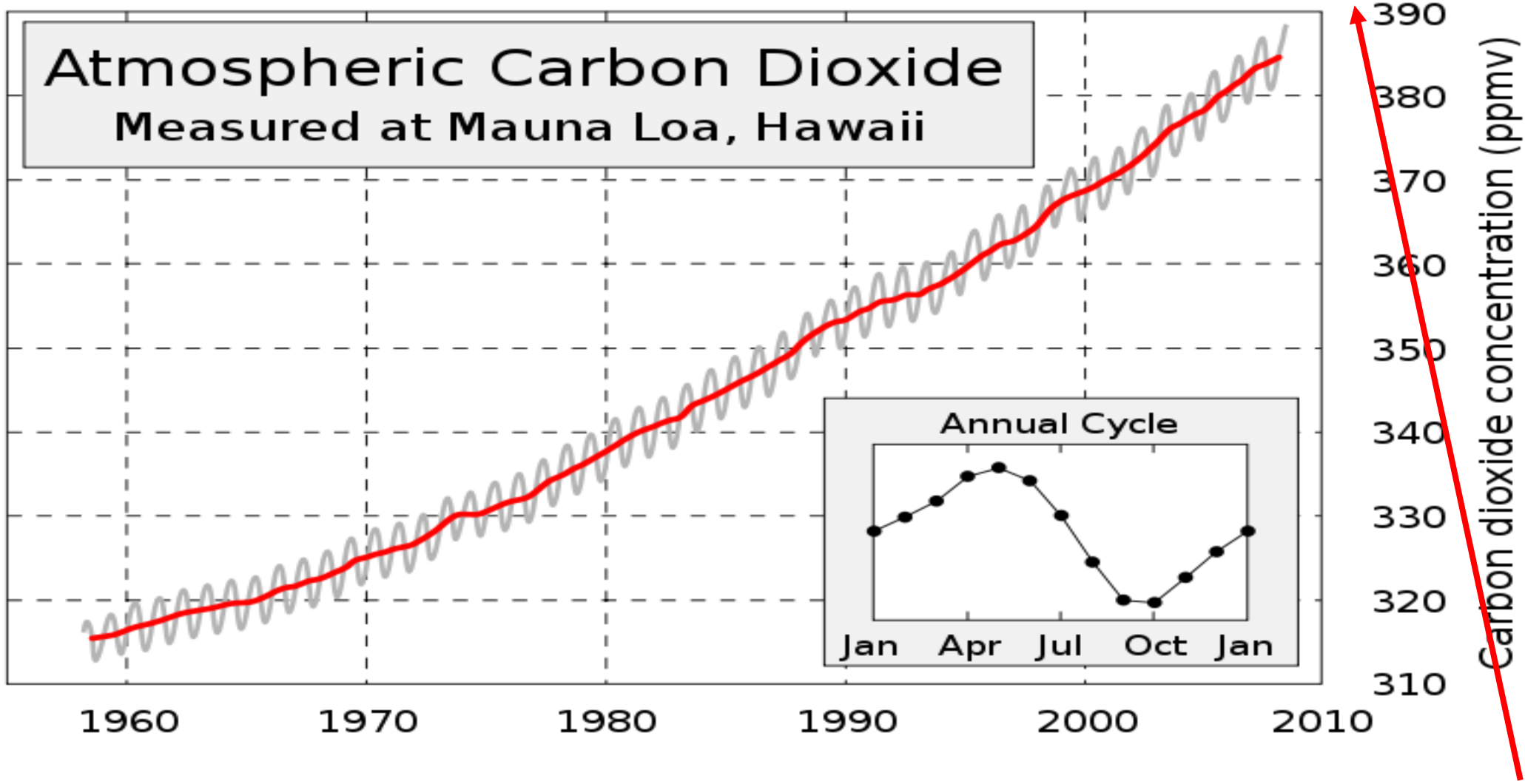
Kuidas tekib stressimälu?

Pärilik, põlvkondadevaheline mälu

Emaliini mälu

Unustamise tähtsus

Kas kõik taimed käituvad ühtemoodi?

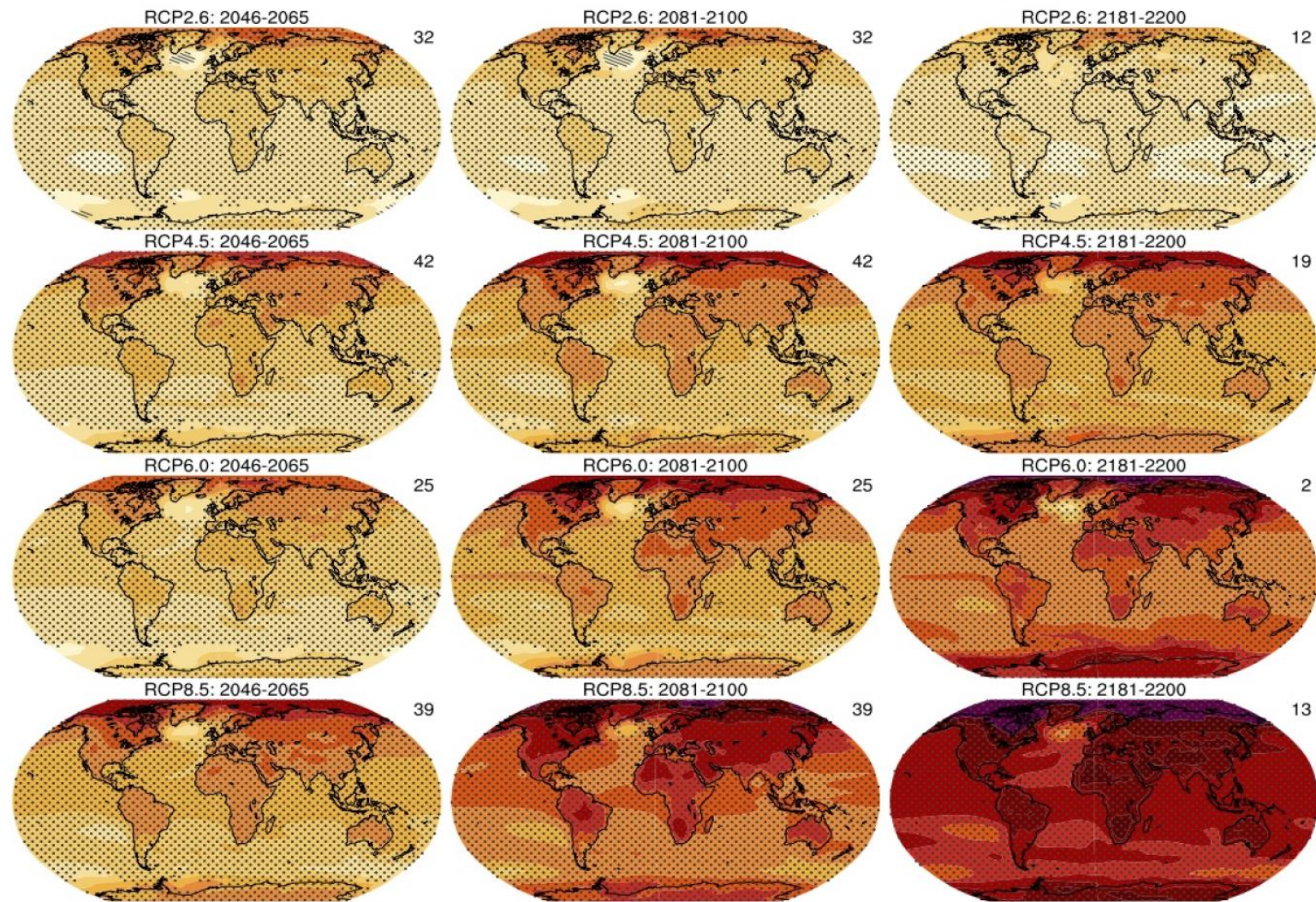


Juuli 2022,
418.90

Probleem CO₂-ga: keskmiselt kõrgem temperatuur ja sagedamad kuumastressi episoodid

Annual mean surface air temperature change

IPCC 2013 (5th assessment report)



ipcc

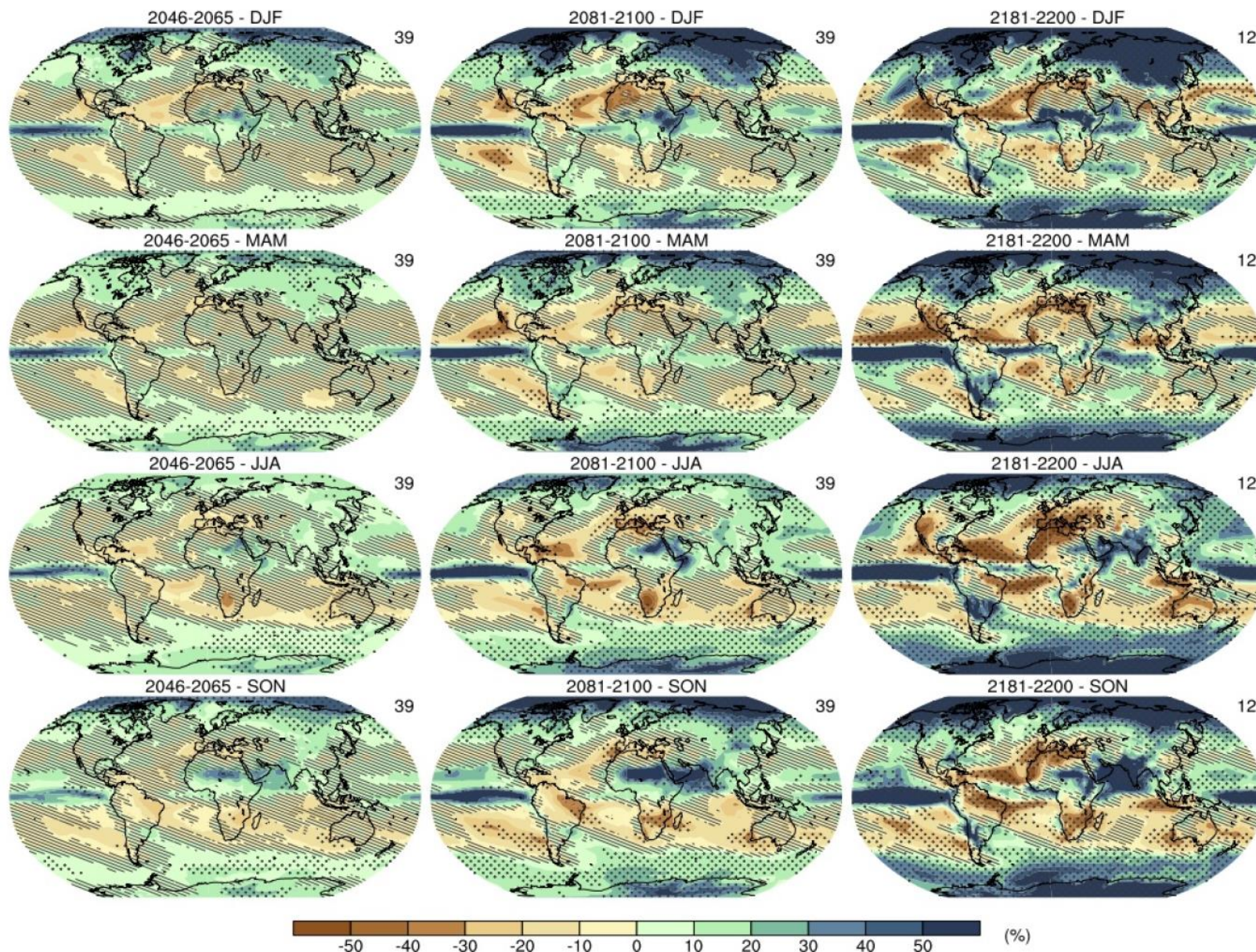
REPORTS SYNTHESIS REPORT WORKING GROUPS ACTIVITIES NEWS
CALENDAR

Sixth Assessment
Report

The Sixth Assessment Report is underway.

Globaalne kliimamuutus: sademed

Seasonal mean percentage precipitation change (RCP8.5)







© 2014 American Meteorological Society
Weather, Climate and Society, 2014, 6, 331–340

Water, Drought, Climate Change, and Conflict in Syria

PETER H. GLEICK

Pacific Institute, Oakland, California

Political Geography 60 (2017) 232–244



ELSEVIER

Contents lists available at [ScienceDirect](#)

Political Geography

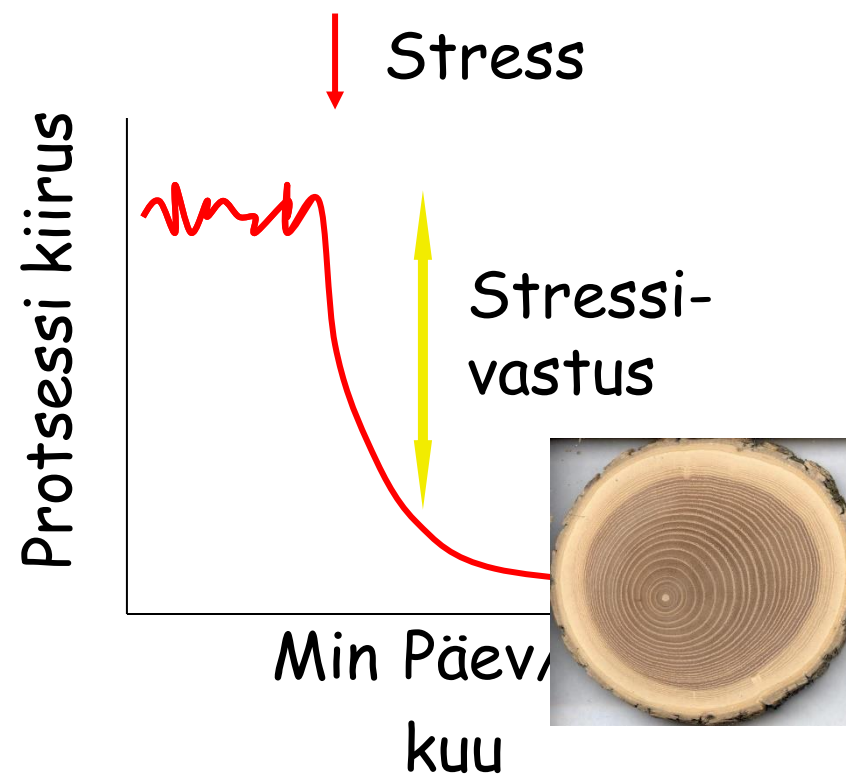
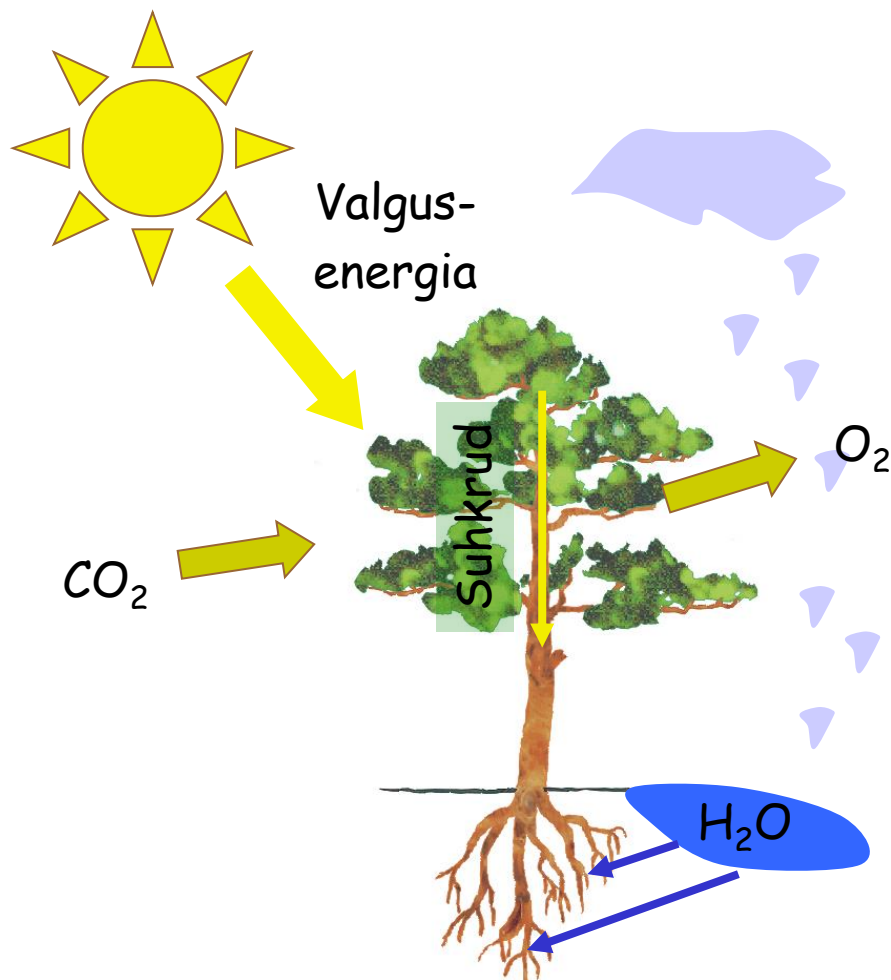
journal homepage: www.elsevier.com/locate/polgeo



Climate change and the Syrian civil war revisited

Jan Selby ^{a,*}, Omar S. Dahi ^b, Christiane Fröhlich ^{c,d}, Mike Hulme ^e

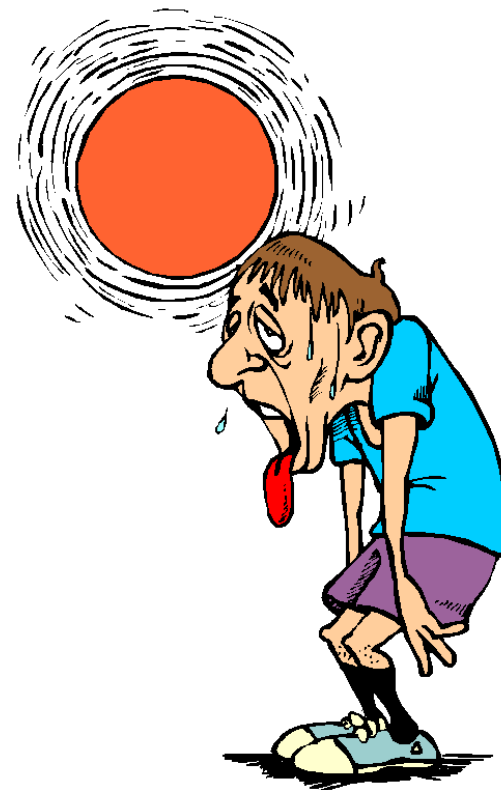
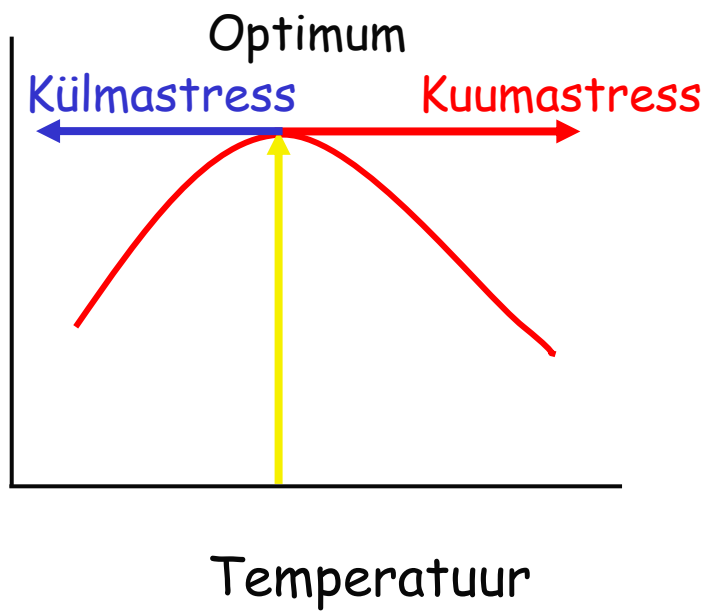
Stress on iga väline tegur, mis piirab taime füsioloogilisi protsesse (fotosüntees, kasv).



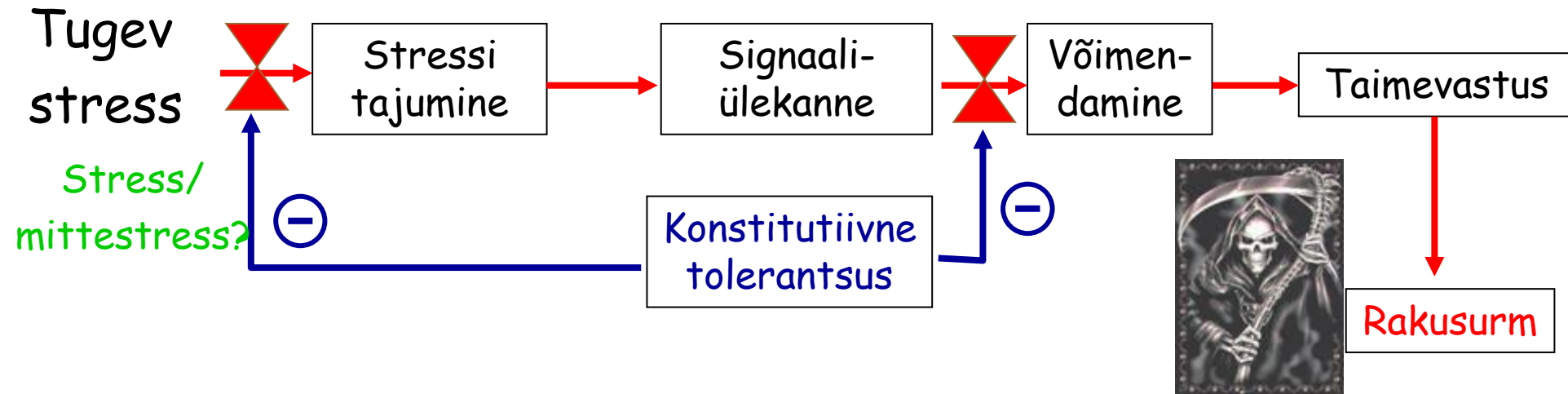
Stress ja füsioloogiline optimum



Fotosünteesi kiirus



Tugev vs. nõrk stress



Review

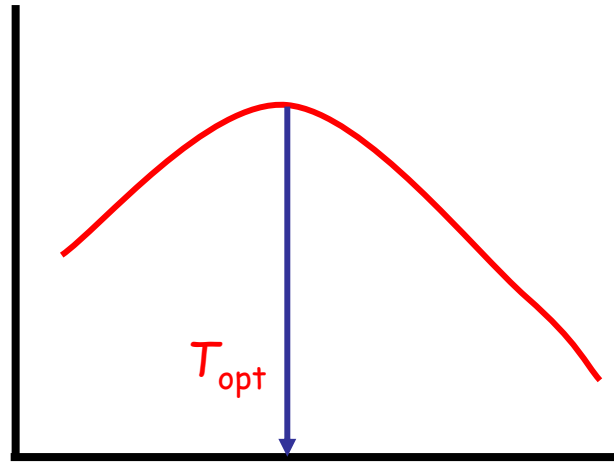
Cell
PRESS

Mild versus severe stress and BVOCs: thresholds, priming and consequences

Ülo Niinemets

Trends in Plant Science Vol.15 No.3

Fotosünteesi kiirus



Temperatuur



THE INDEPENDENT

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Amazon rainforest 'could become a desert'

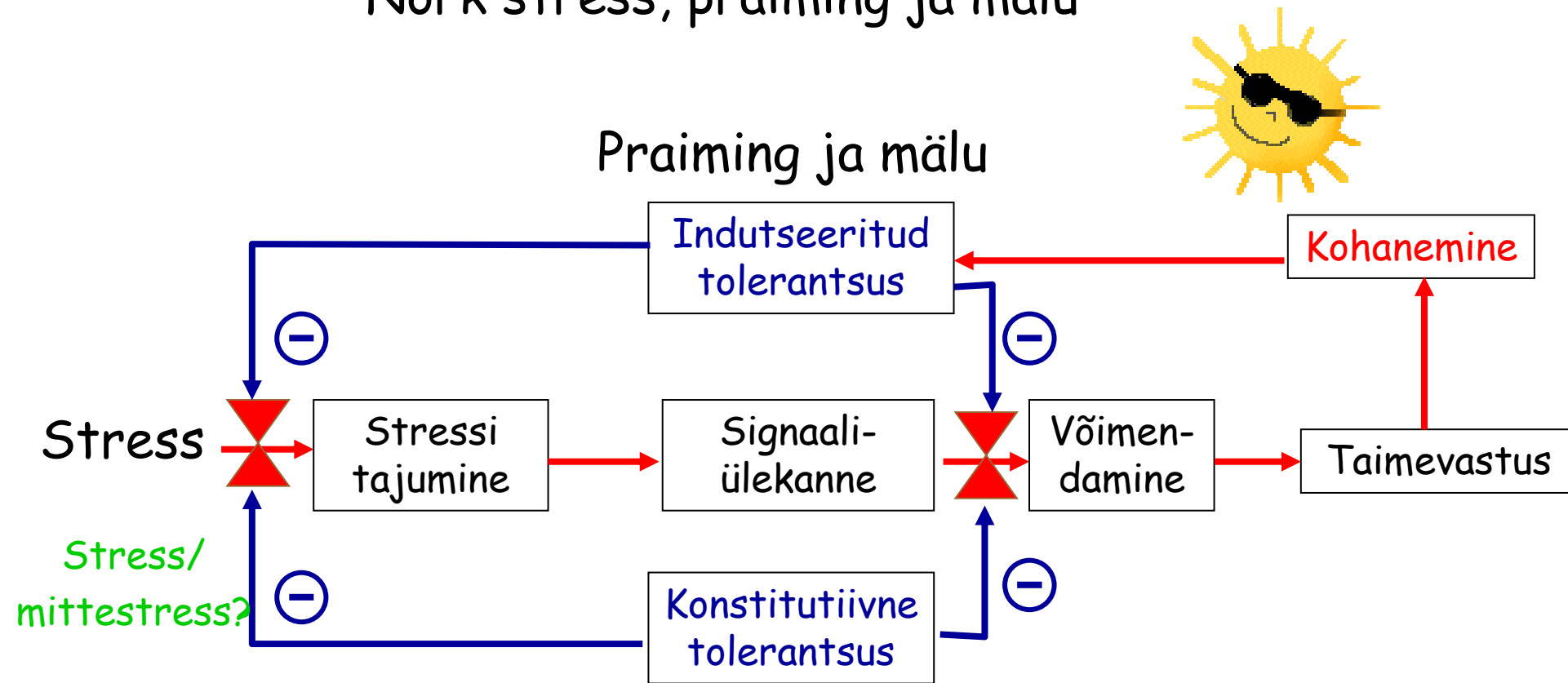
And that could speed up global warming with 'incalculable consequences', says alarming new research

By Geoffrey Lean in Manaus and Fred Pearce

Sunday, 23 July 2006

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Nõrk stress, praiming ja mälu



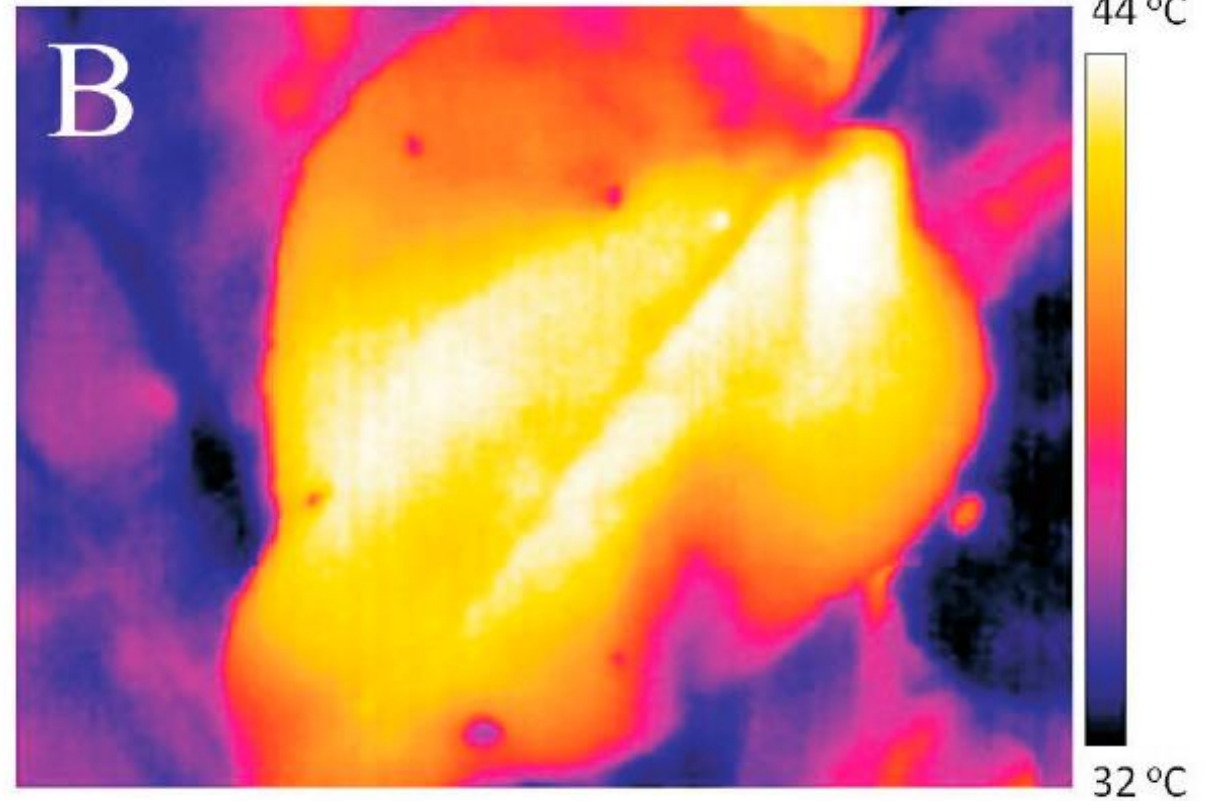
Review

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Trends in Plant Science Vol.15 No.3



plants



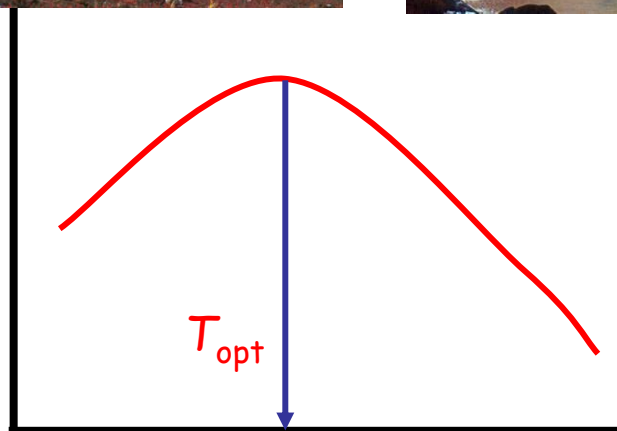
Article *Plants* 2019, 8, 145; doi:10.3390/plants8060145

Responses of Aspen Leaves to Heatflecks: Both Damaging and Non-Damaging Rapid Temperature Excursions Reduce Photosynthesis

Katja Hüve ¹, Irina Bichele ², Hedi Kaldmäe ¹ , Bahtijor Rasulov ¹, Fernando Valladares ³ and Ülo Niinemets ^{1,4,*} 



Fotosünteesi kiirus

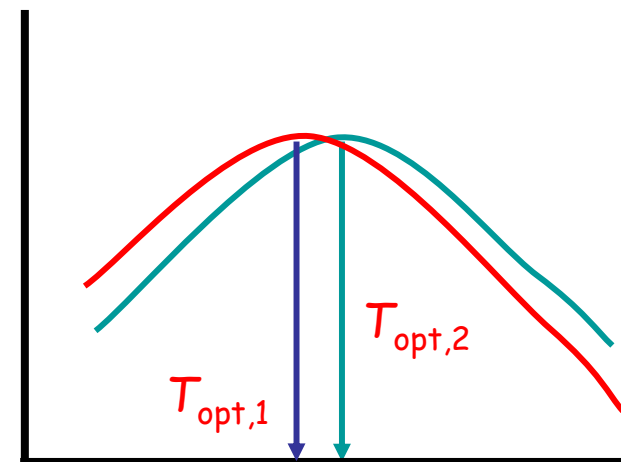


Temperatuur

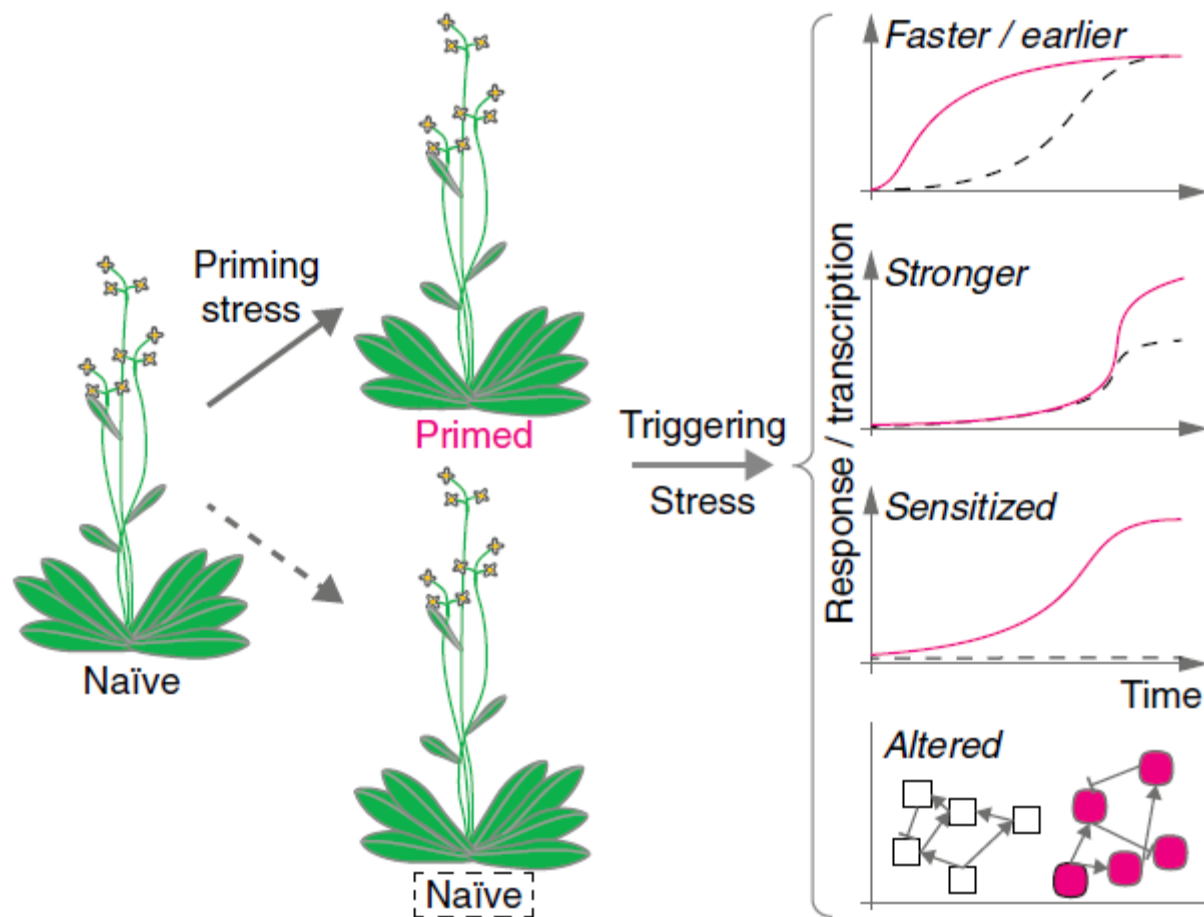


Keskmine temperatuur

Fotosünteesi kiirus



Temperatuur



Lämke and Bäurle *Genome Biology* (2017) 18:124
DOI 10.1186/s13059-017-1263-6

Genome Biology

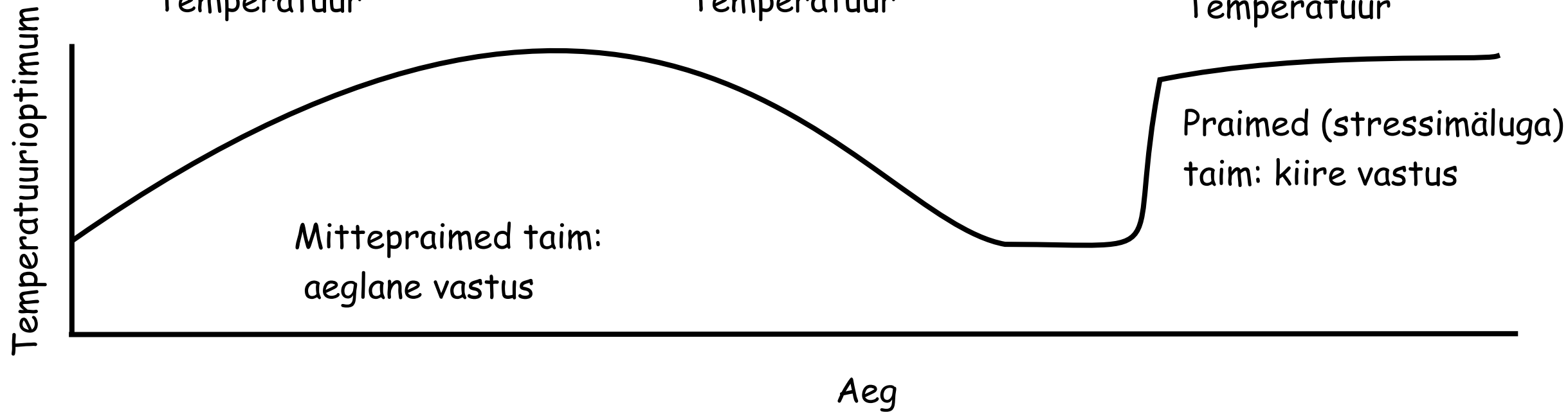
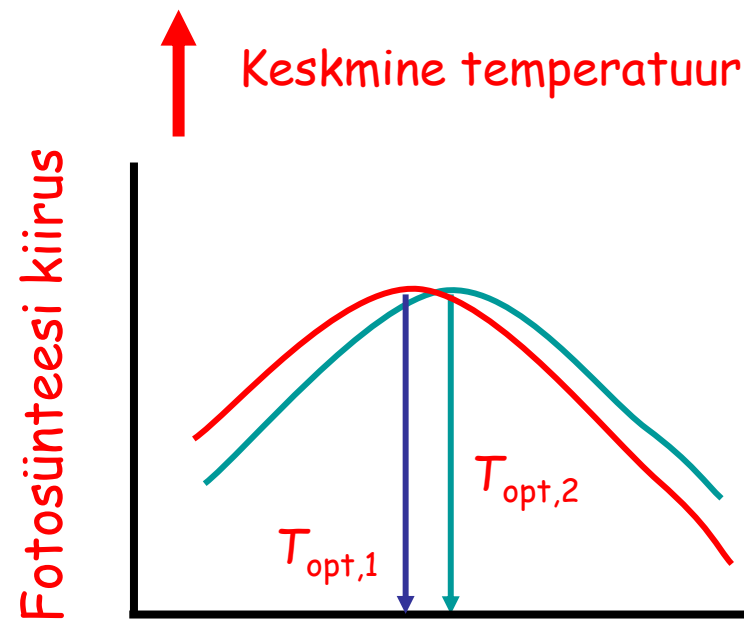
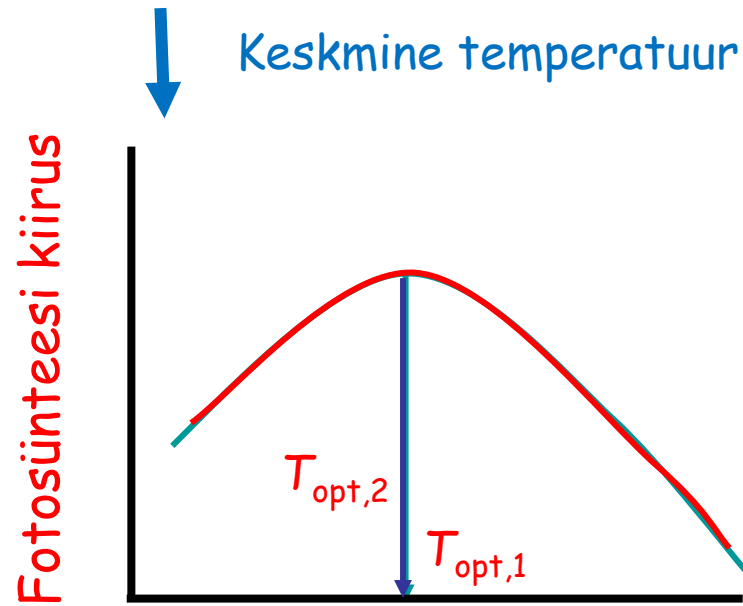
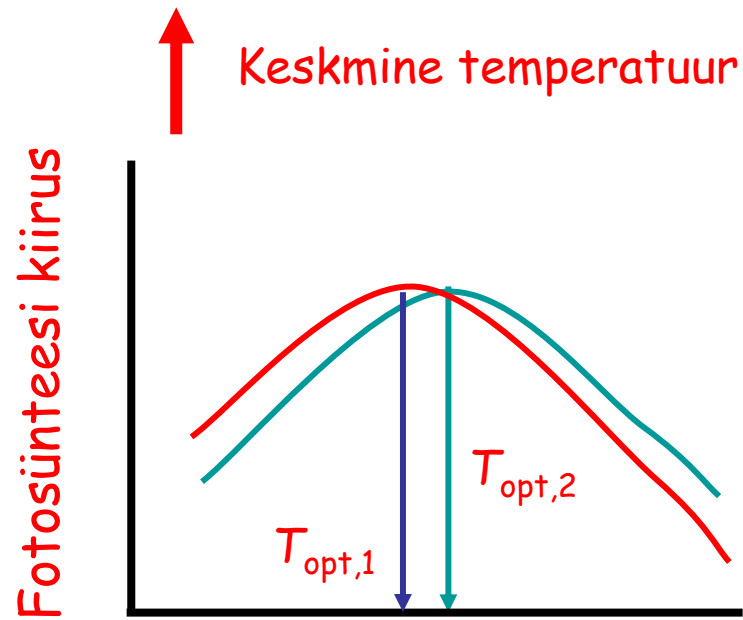
REVIEW

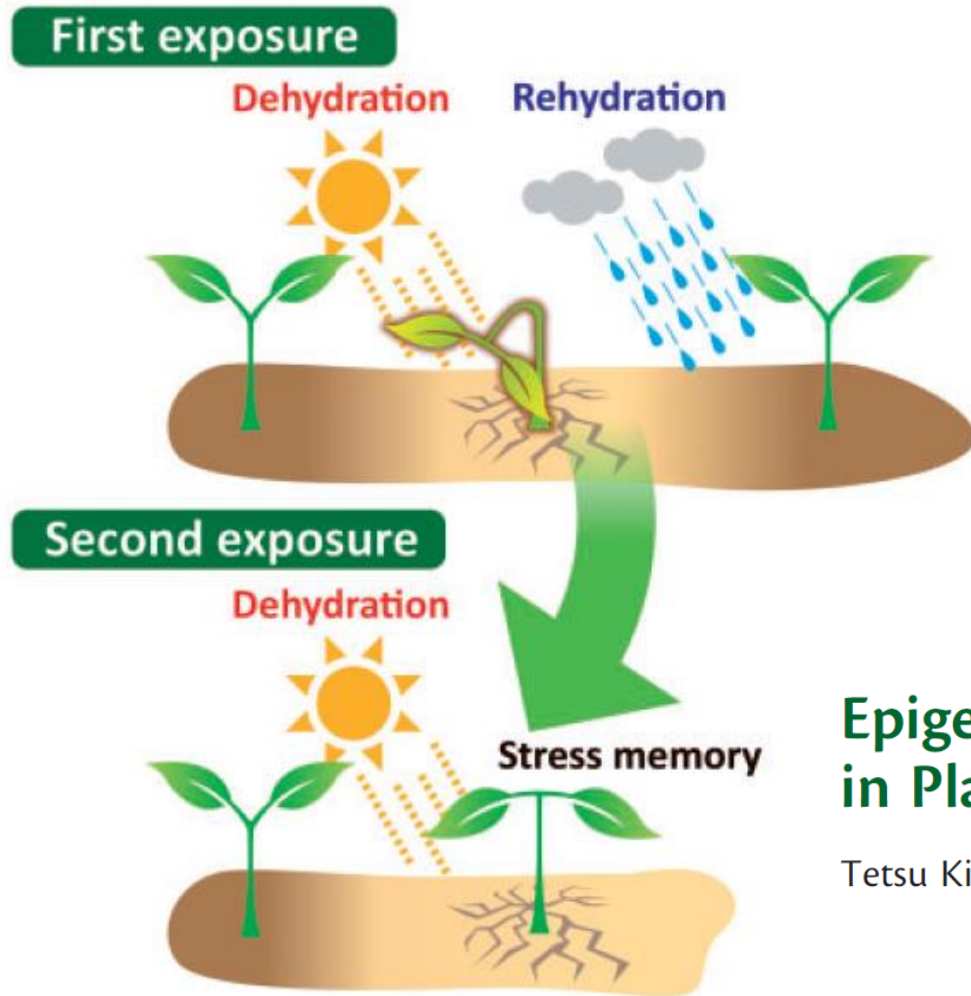
Open Access



Epigenetic and chromatin-based mechanisms in environmental stress adaptation and stress memory in plants

Jörn Lämke and Isabel Bäurle*



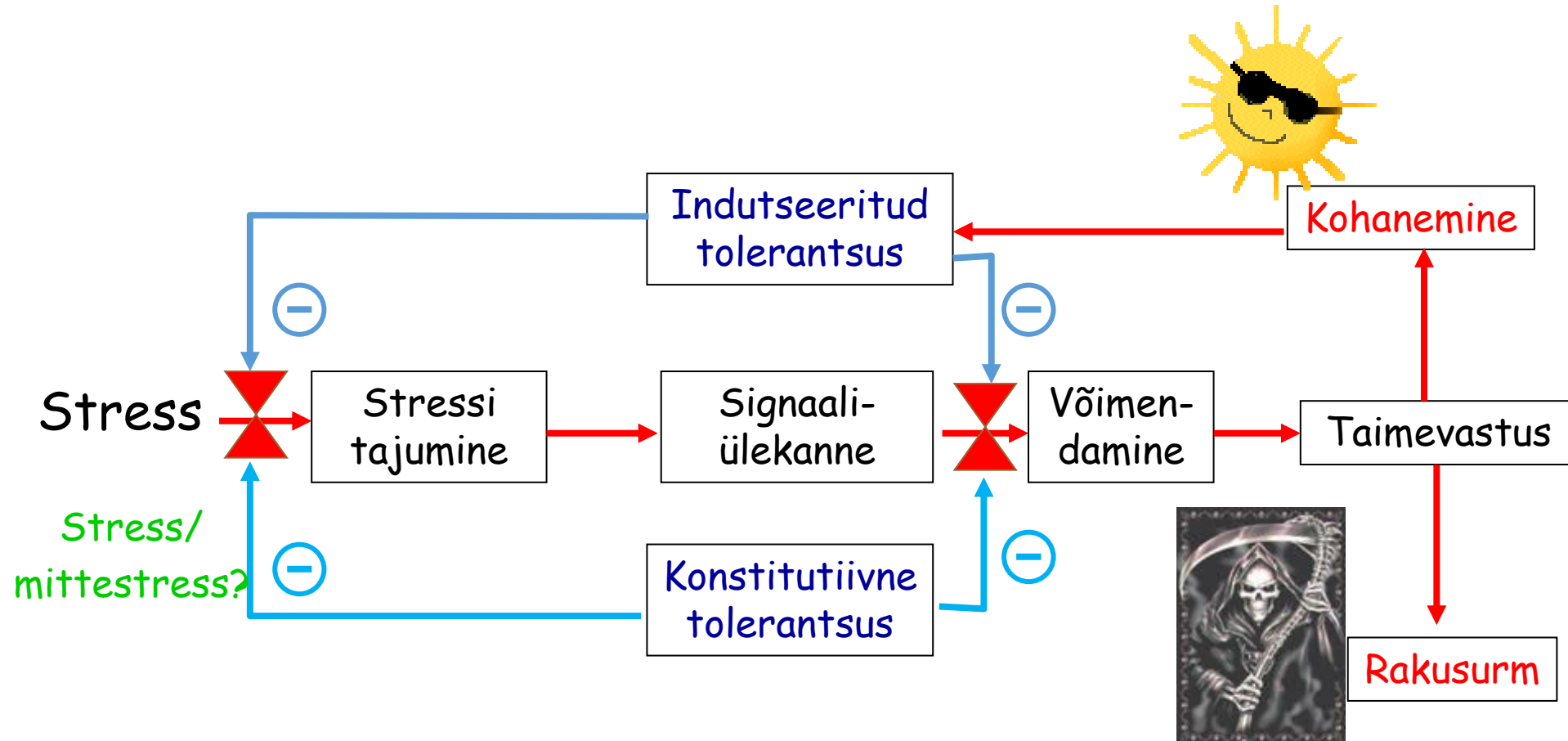


Epigenetic Memory for Stress Response and Adaptation in Plants

Tetsu Kinoshita^{1,*} and Motoaki Seki^{1,2,3}

Plant Cell Physiol. 55(11): 1859–1863 (2014) doi:10.1093/pcp/pcu125, Advance Access publication on 8 October 2014, available FREE online at www.pcp.oxfordjournals.org

Stressisignaaliid, priming ja mälu



Review

Cell
PRESS

Mild versus severe stress and BVOCs: thresholds, priming and consequences

Ülo Niinemets

Trends in Plant Science Vol.15 No.3

Loengukava

Stress ja taimed. Kohanemine ja stressimälu

Kuidas tekib stressimälu?

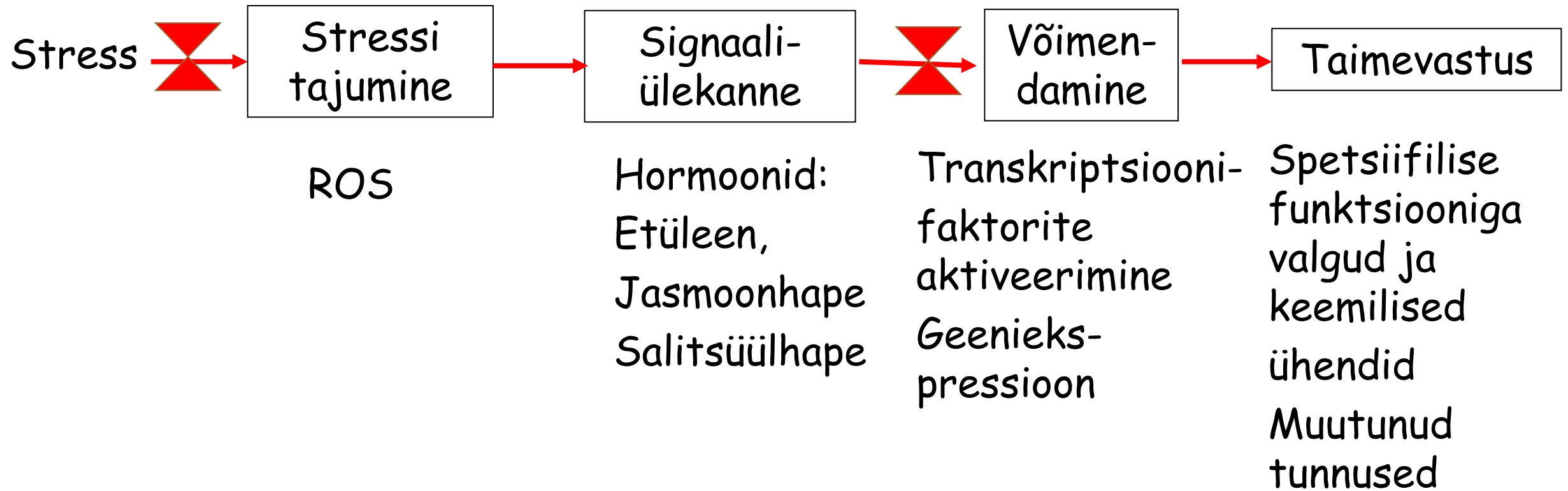
Pärilik, põlvkondadevaheline mälu

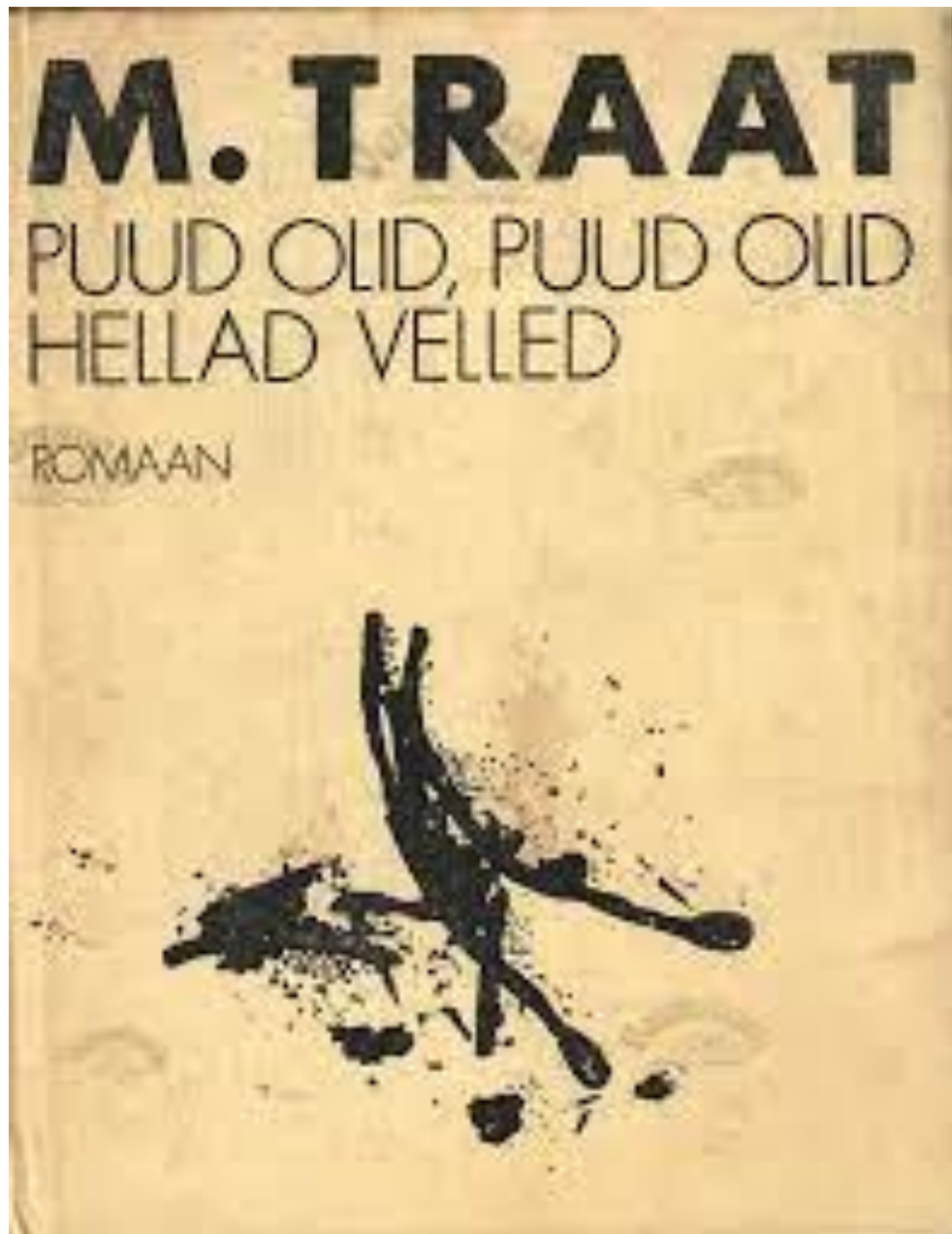
Emaliini mälu

Unustamise tähtsus

Kas kõik taimed käituvad ühtemoodi?

Stressivastus ja kohanemine



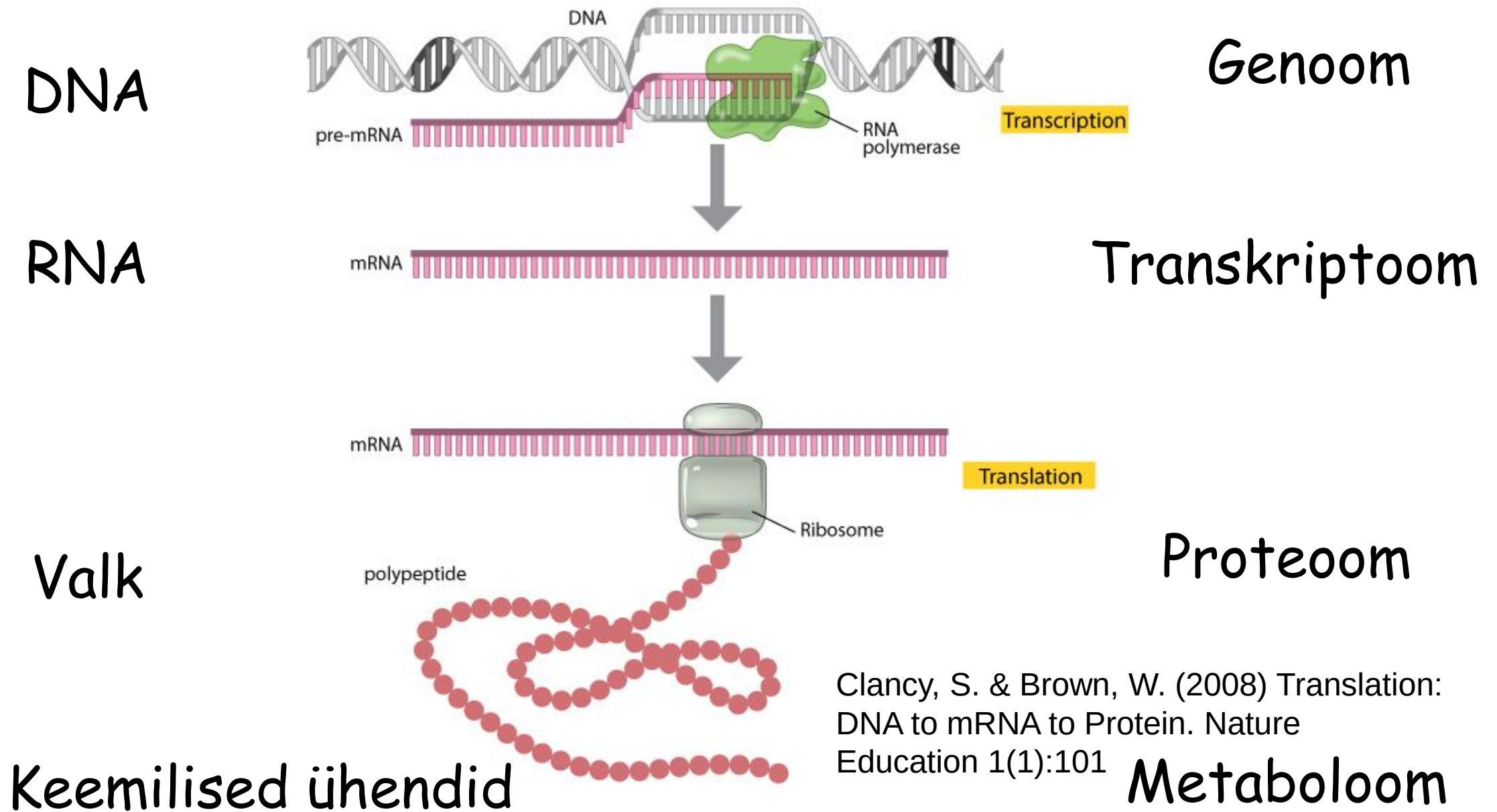


..puud, hellad velled, tõmbasid külge, sosistades, kutsudes haljas kevadõhtus: „Tule tänna! Ärä uneta vannu sõpru! Kui karjalits ollit, tükset iks külma, vihma nink tuule iist me varju. Joose, torma me poole, pää iin! Tuu om sul kivist, ravvast, ei lää katski, kui kolksat vasta түvve. Tule tagasi mõtsa varju, pissetü nink äbistetü!” (lk. 84)

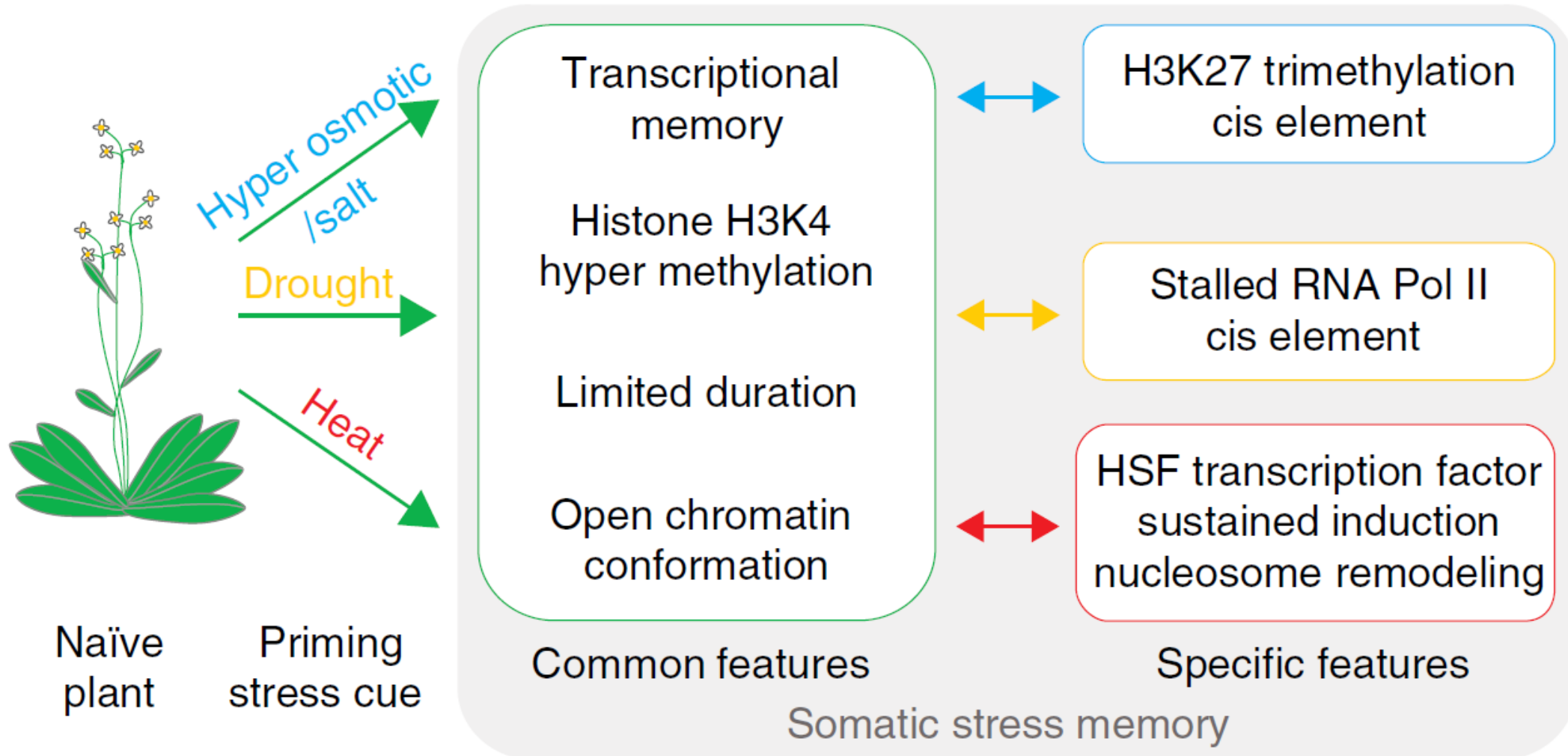
„Enneki et pirde mõist ta küll äste kisku, loogatais pirde om täl silmäpilk kistu, ää õhukese pirru, miä ei ole nõrruki nui osavat pirrukiskjat, taa osad esä...” lk. 131



Transkriptsioon, translatsioon??



Milles seisneb stressimälu?

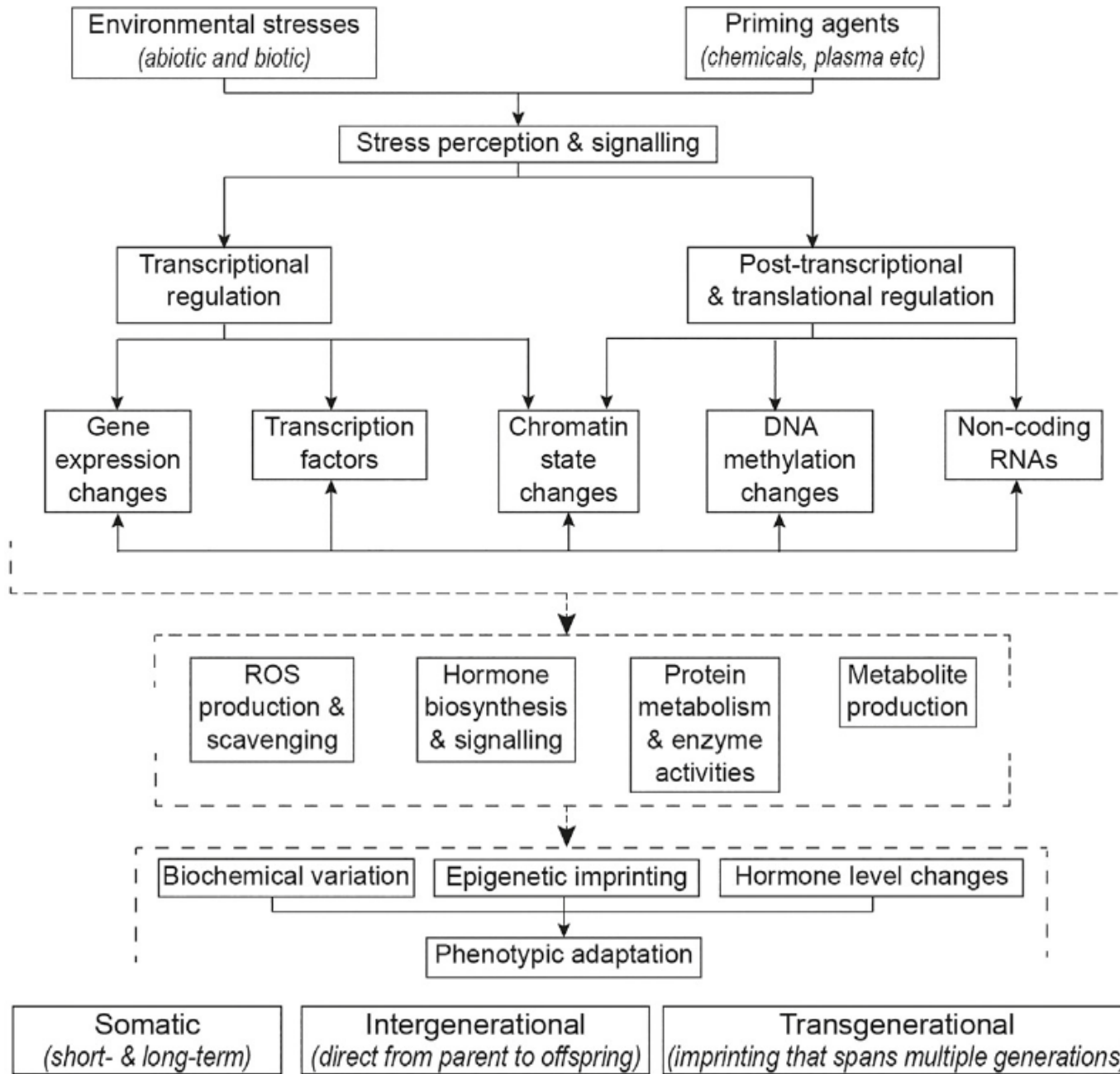


HSF: heat shock transcription factor

Stress stimuli

Establishing stress memory & feedback loops

Stress memory



Praiming

Mälu

Kohanemine

Trends in
Plant Science

Special issue: Climate change and sustainability I

Review

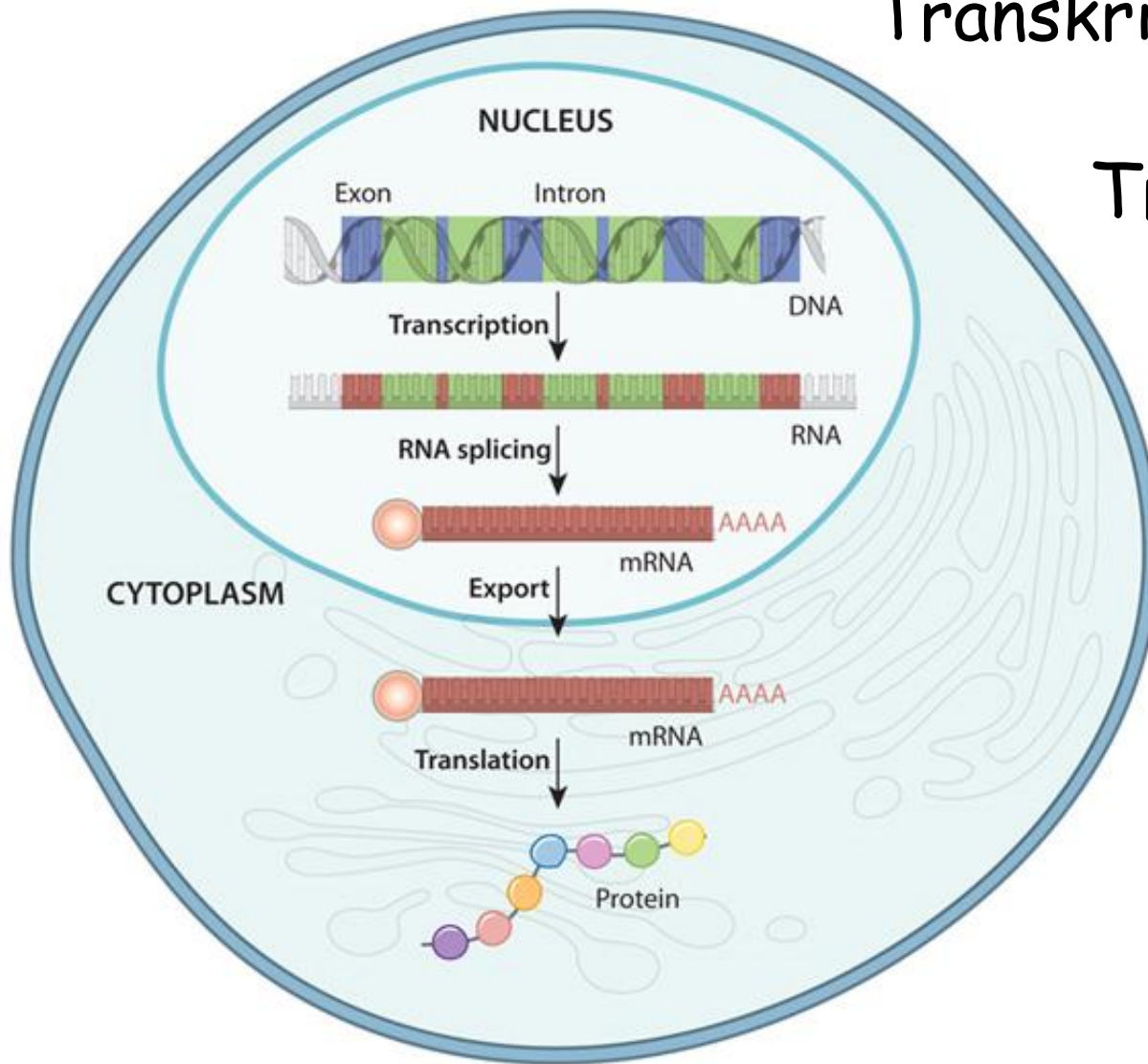
Priming crops for the future: rewiring stress memory

Haipai Liu ,¹ Amanda J. Able ,¹ and Jason A. Able ^{1,*}

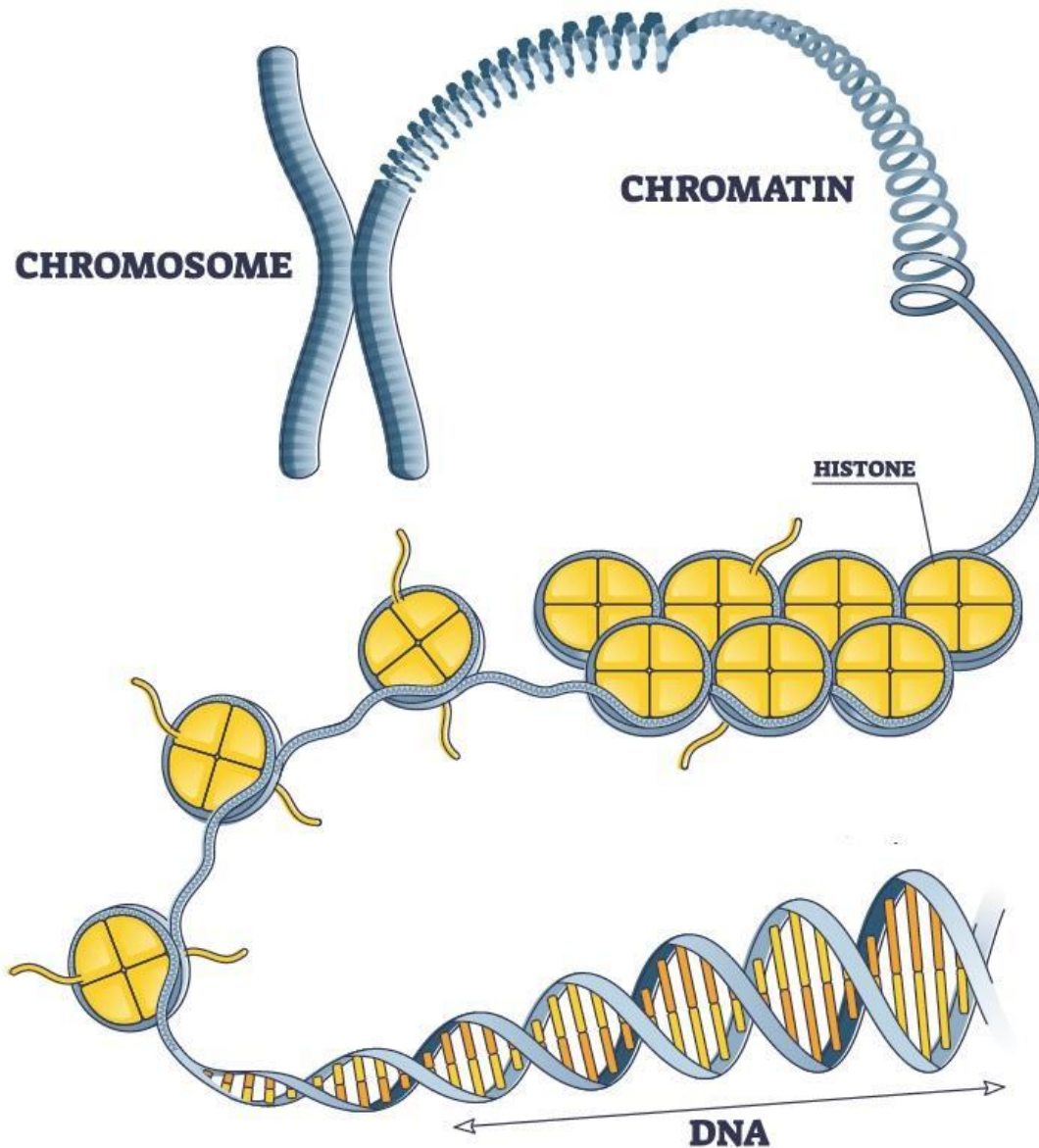
Trends in Plant Science, July 2022, Vol. 27, No. 7

Transkriptsiooniline stressimälu?

Transkriptsioon: DNA → RNA

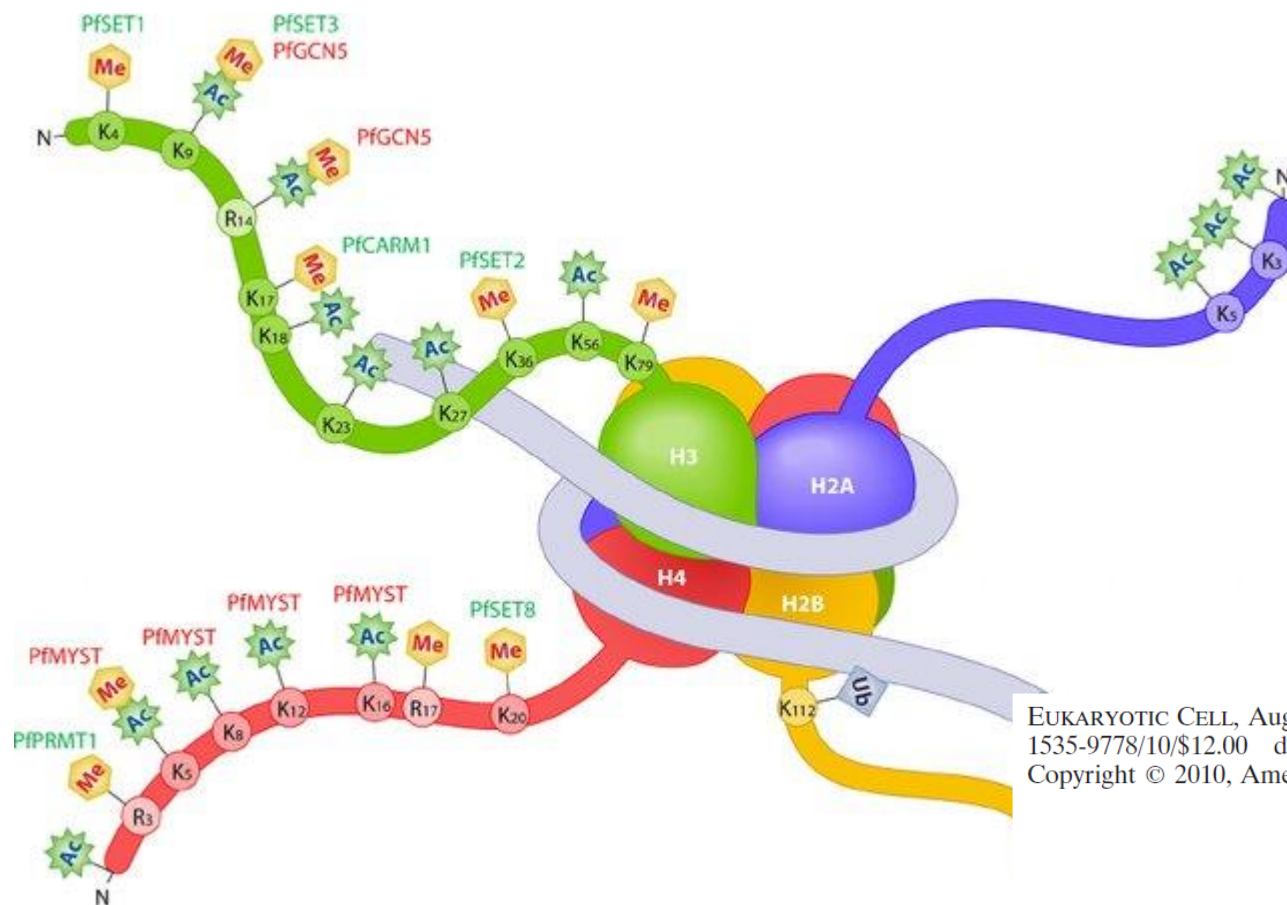


Translatsioon: RNA → valk,
muutus taime fenotüübis



DNA on kromosoomides kokku pakitud (kromatiin). Selleks, et transkriptsioon saaks toimuda, peab RNA polümeraasile olema ligipääs DNA-le

Histoonid: DNA-d pakkivad valgud



Histoonide metüleerimine ja
atsetüleerimine muudab
kromatiini struktuuri

EUKARYOTIC CELL, Aug. 2010, p. 1138–1149
1535-9778/10/\$12.00 doi:10.1128/EC.00036-10
Copyright © 2010, American Society for Microbiology. All Rights Reserved.

MINIREVIEWS

Chromatin-Mediated Epigenetic Regulation in the
Malaria Parasite *Plasmodium falciparum*[▽]

Liwang Cui* and Jun Miao

REVIEW

Open Access



Histone H3 lysine K4 methylation and its role in learning and memory

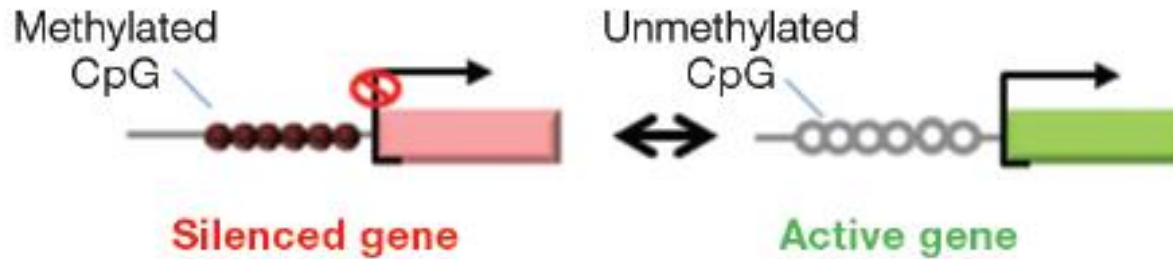
Bridget E. Collins, Celeste B. Greer, Benjamin C. Coleman and J. David Sweatt^{*}

Modifiers of H3K4 methylation are needed for memory formation, shown through animal studies, and many of the same modifiers are mutated in human cognitive diseases. Cognitive impairment in such patients often manifests as intellectual disability, consistent with a role for H3K4 methylation in learning and memory.

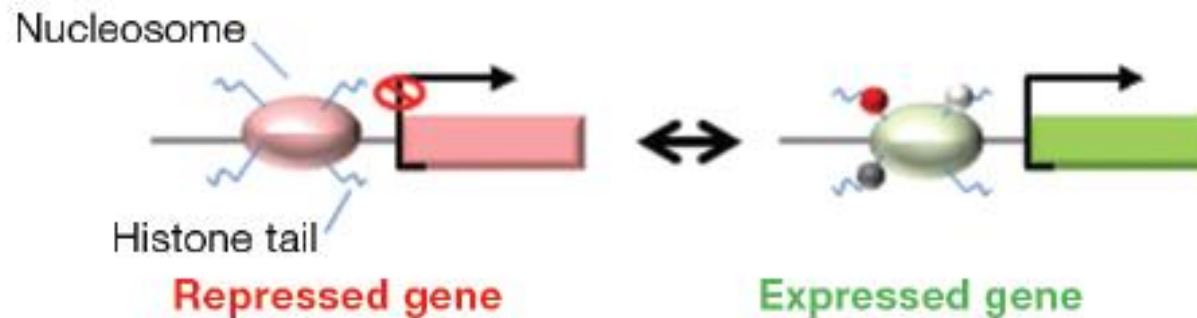
DNA metüleerimine ja mälu

b

DNA methylation



Histone modifications



Gudjonsson JE, Krueger G. A role for epigenetics in psoriasis: methylated Cytosine-Guanine sites differentiate lesional from nonlesional skin and from normal skin. *J Invest Dermatol.* 2012 Mar;132(3 Pt 1):506-8.

DNA metüleerimine ja mälu: noor vs. vana taim



Acacia koa

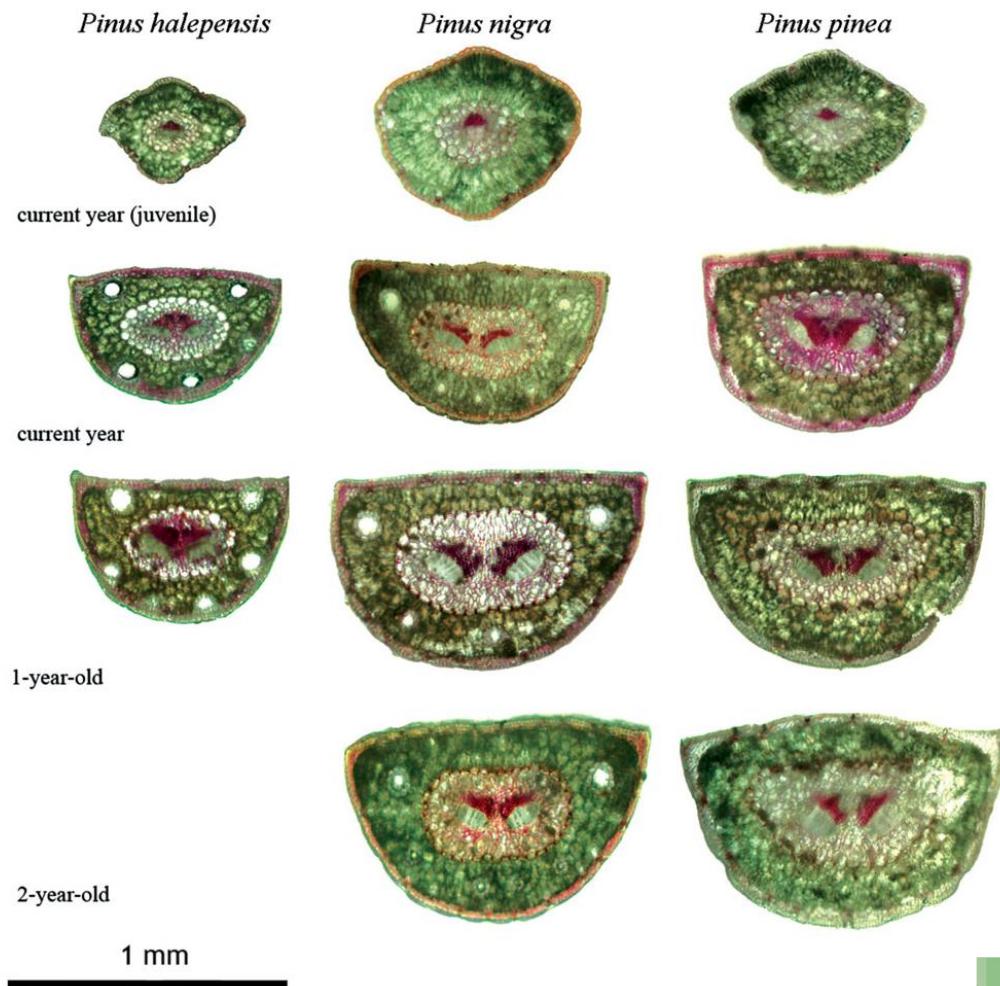
<https://davesgarden.com/guides/pf/showimage/17677>



Pinus pinea

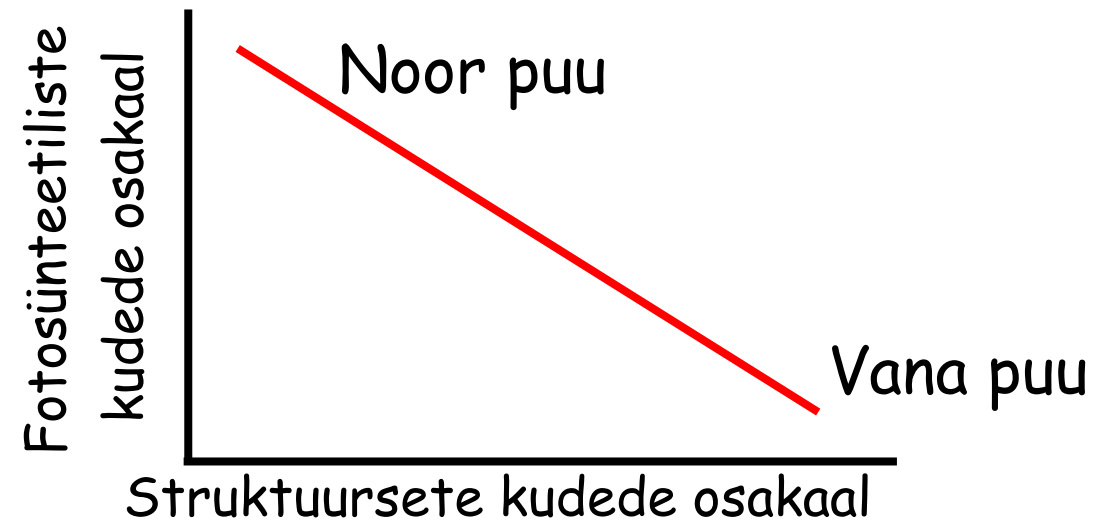
<https://www.walterreeves.com/landscaping/italian-stone-pine-juvenile-foliage-and-mature-foliage/>





Noor puu: kõrge fotosünteesivõime, väike struktuursete kudede osakaal

Vana puu: madal fotosünteesivõime, suur struktuursete kudede osakaal



Tree Physiology 38, 543–557
doi:10.1093/treephys/tpx139

Research paper

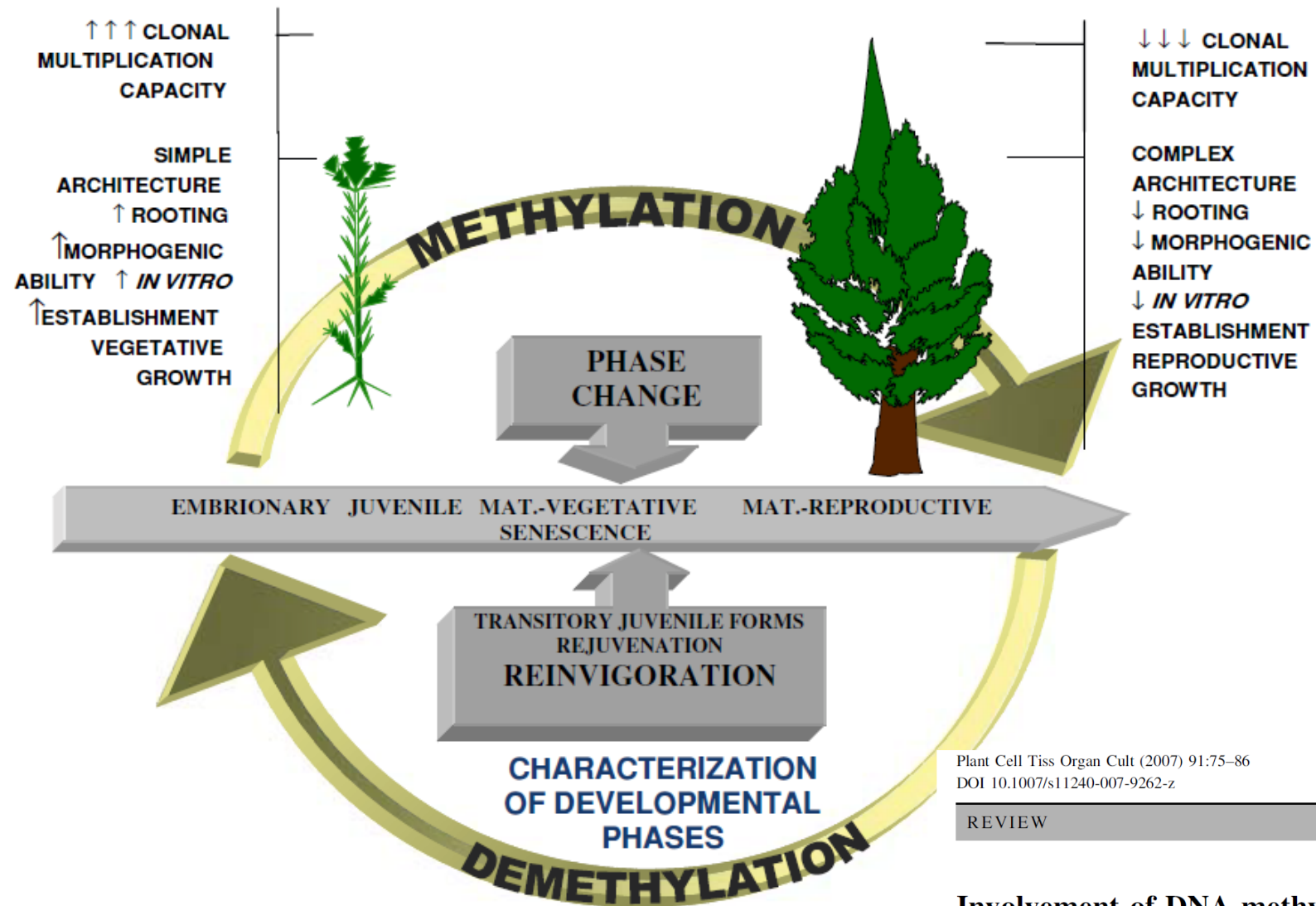
A major trade-off between structural and photosynthetic investments operative across plant and needle ages in three Mediterranean pines

Vivian Kuusk¹, Ülo Niinemets^{1,2,5} and Fernando Valladares^{3,4}

Genomic DNA methylation of juvenile and mature *Acacia mangium* micropropagated in vitro with reference to leaf morphology as a phase change marker

FRANC-CHRISTOPHE BAURENS,¹ JORIS NICOLLEAU,^{1,2} THIERRY LEGAVRE,¹ JEAN-LUC VERDEIL¹ and OLIVIER MONTEUUIS^{2,3}





Plant Cell Tiss Organ Cult (2007) 91:75–86
DOI 10.1007/s11240-007-9262-z

REVIEW

Involvement of DNA methylation in tree development and micropropagation

Luis Valledor · Rodrigo Hasbún · Mónica Meijón · Jose Luis Rodríguez · Estrella Santamaría · Marcos Viejo · Maria Berdasco · Isabel Feito · Mario F. Fraga · Maria Jesús Cañal · Roberto Rodríguez

Tagasi lapsepõlve: epigeneetilise mälu kaotus puudel



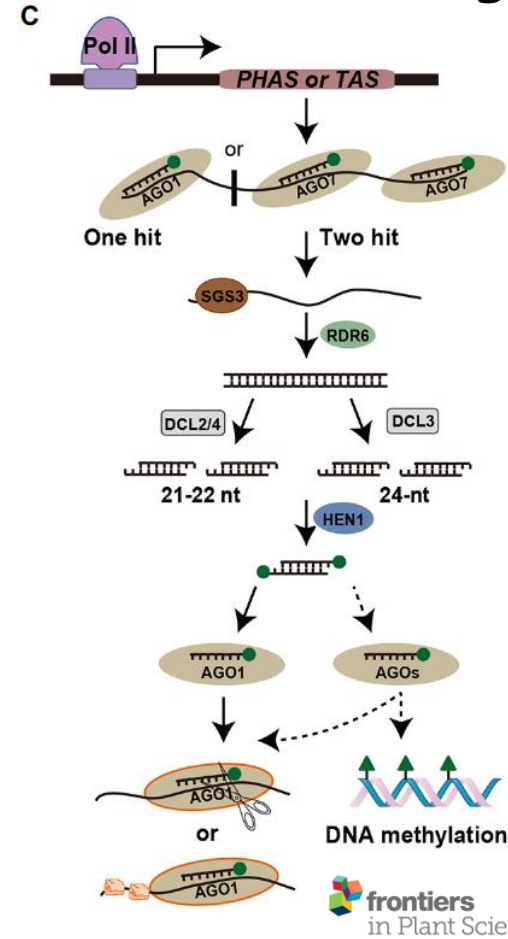
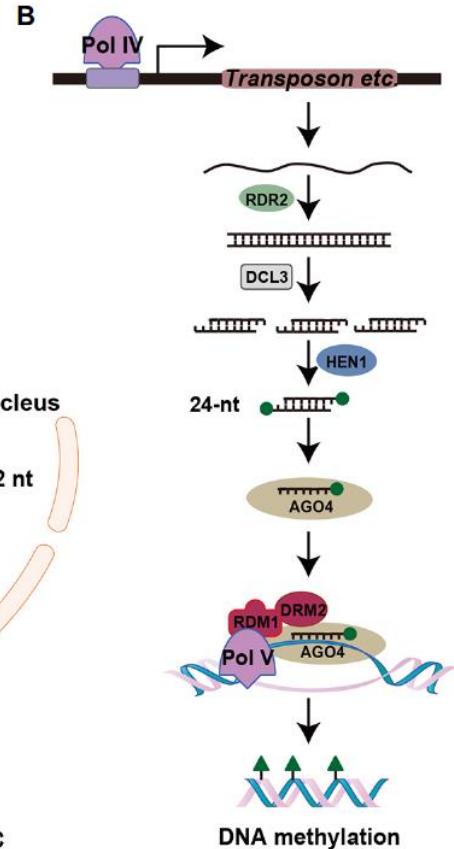
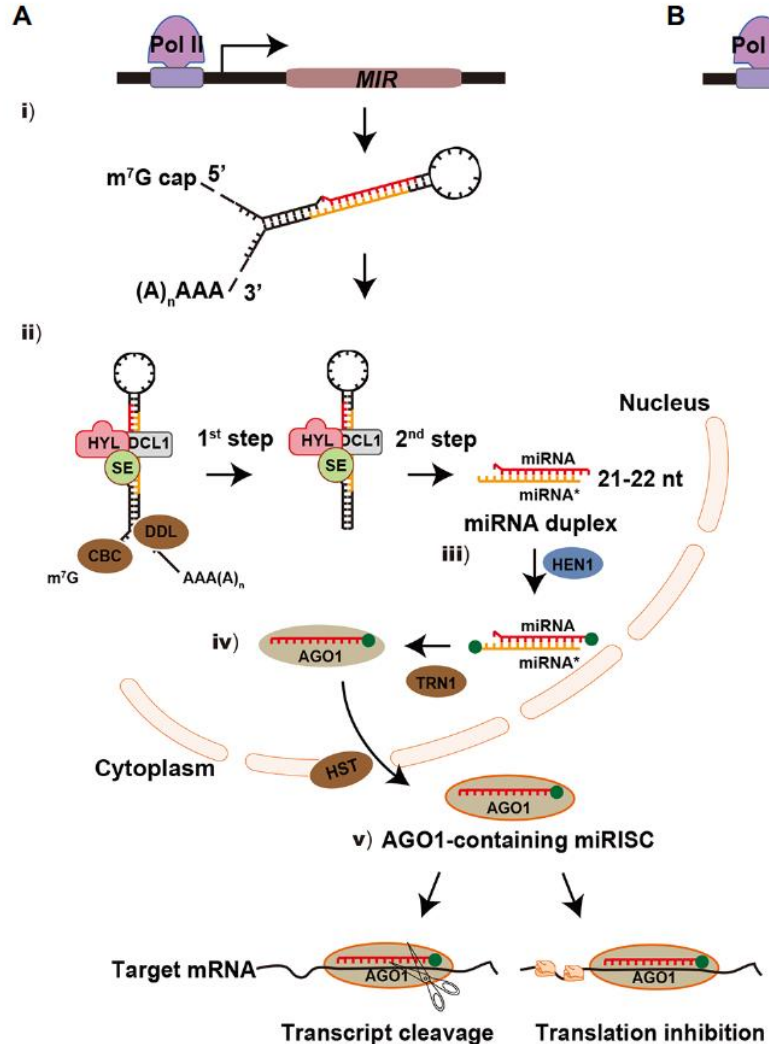
<https://commons.wikimedia.org/w/index.php?curid=837883>



<http://www.hearnearboriculture.com/blog/the-tree-of-the-month-for-july-2016-the-lime-or-linden-tree>

Väikesed mittekodeerivad RNA-d

miRNA (mikro-RNA) siRNA (väike sekkuv RNA, vaigistav RNA)



Small RNAs: The Essential Regulators in Plant Thermotolerance

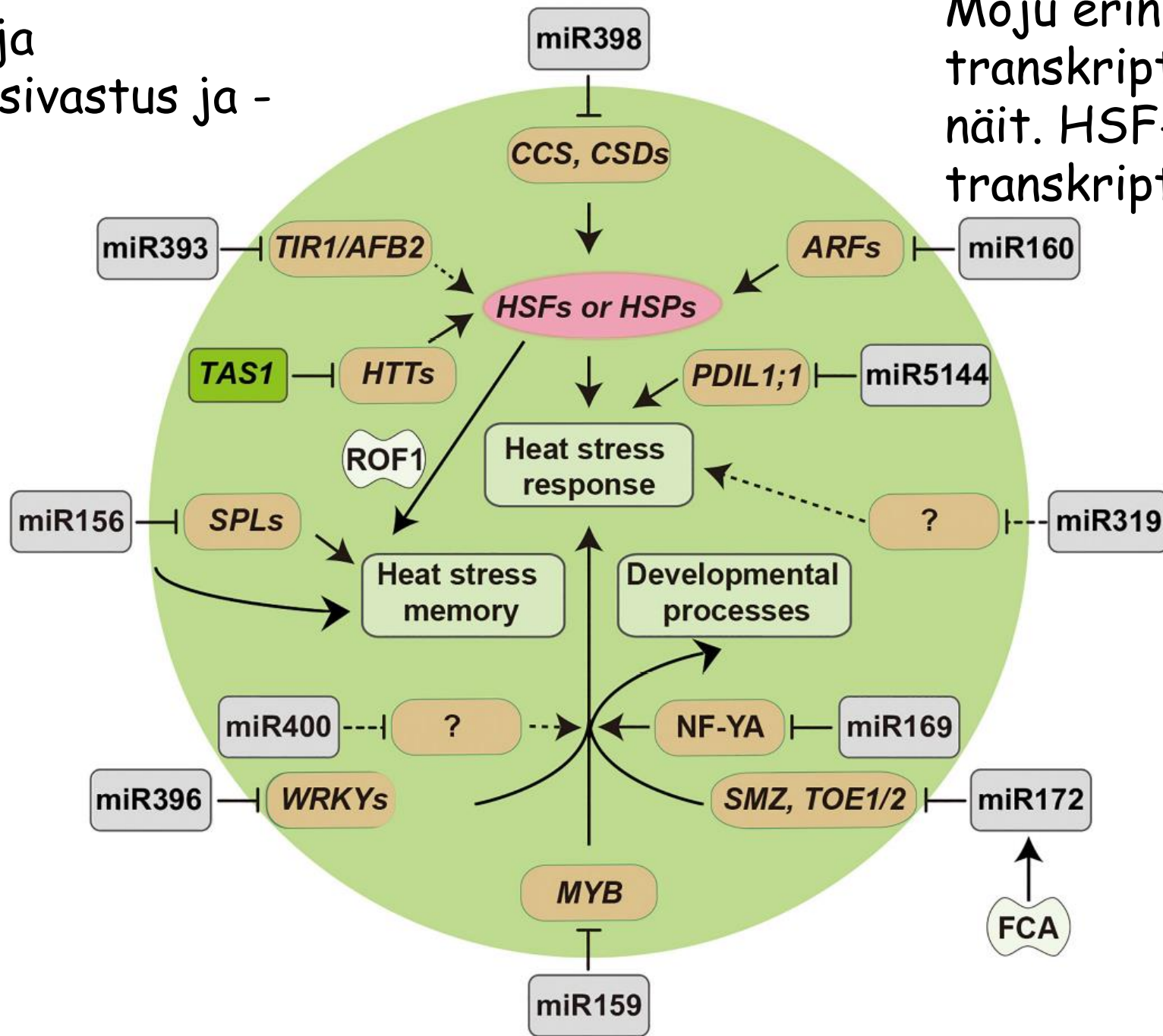
Zhi-Fang Zuo^{1,2}, Wenbo He¹, Jing Li¹, Beixin Mo¹ and Lin Liu^{1*}

REVIEW
published: 17 September 2021
doi: 10.3389/fpls.2021.726762

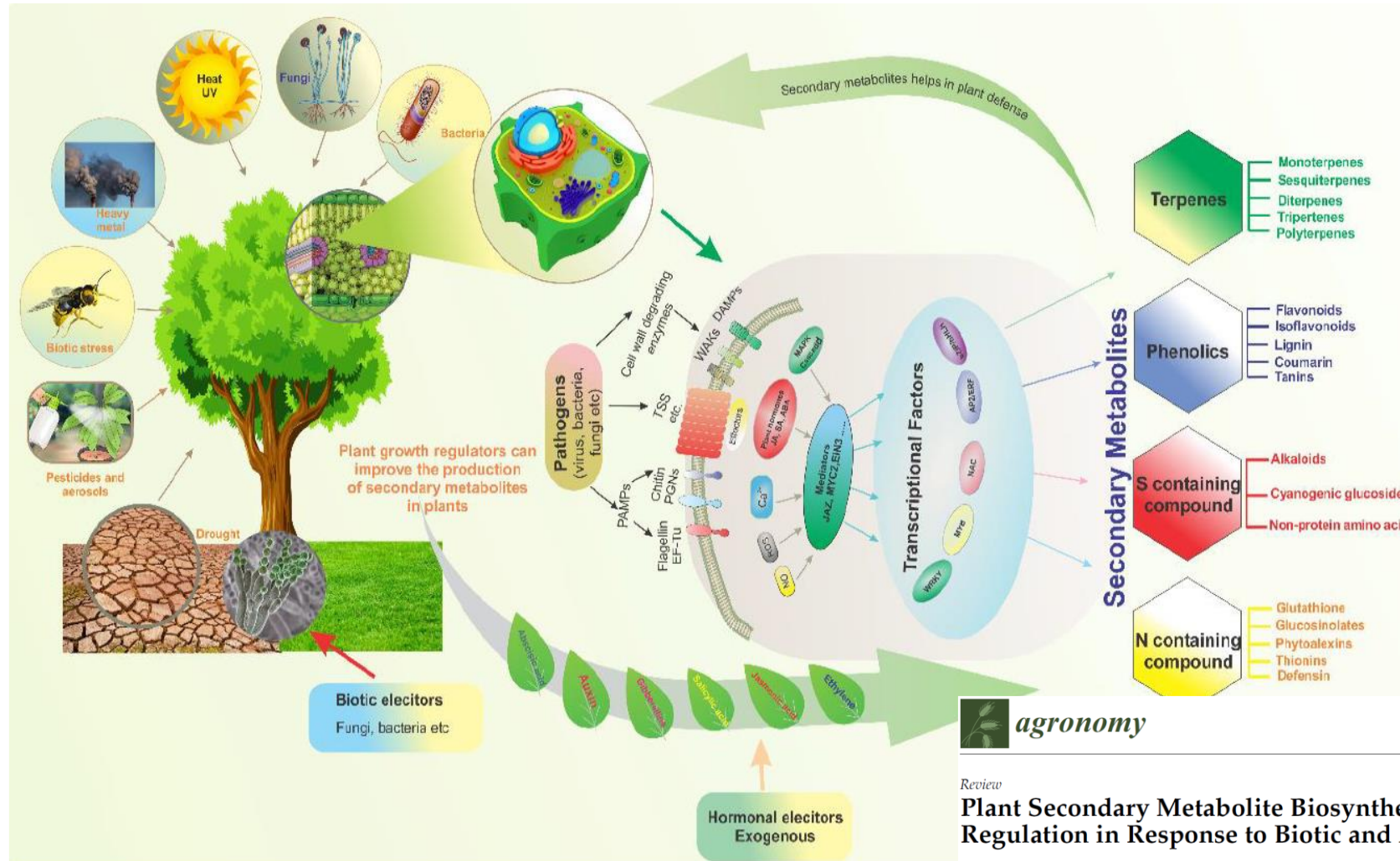
AGO - argonaut valk

MikroRNA ja
kuumastressivastus ja -
mälu

Mõju erinevatele
transkriptsioonifaktoritele,
näit. HSF- kuumastressi
transkriptsioonifaktor



Keemiline mälu: stressi toimetel kaitsvate ühendite akumulereerumine



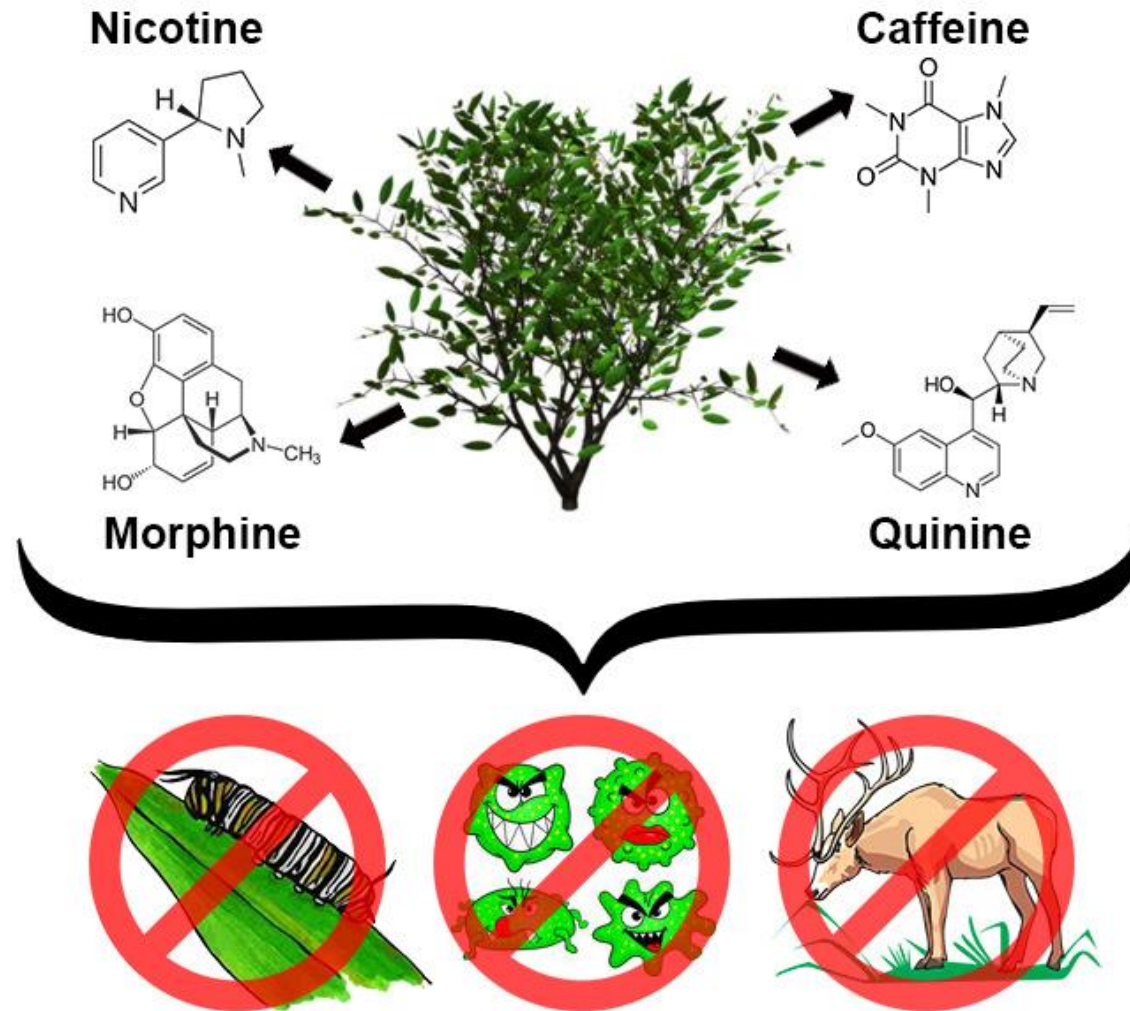
Review

Plant Secondary Metabolite Biosynthesis and Transcriptional Regulation in Response to Biotic and Abiotic Stress Conditions

Rahmatullah Jan ^{1,2,*}, Sajjad Asaf ^{3,†}, Muhammad Numan ⁴, Lubna ⁵ and Kyung-Min Kim ^{1,2,*}

Agronomy 2021, 11, 968. <https://doi.org/10.3390/agronomy11050968>

Plant Defense: Alkaloids

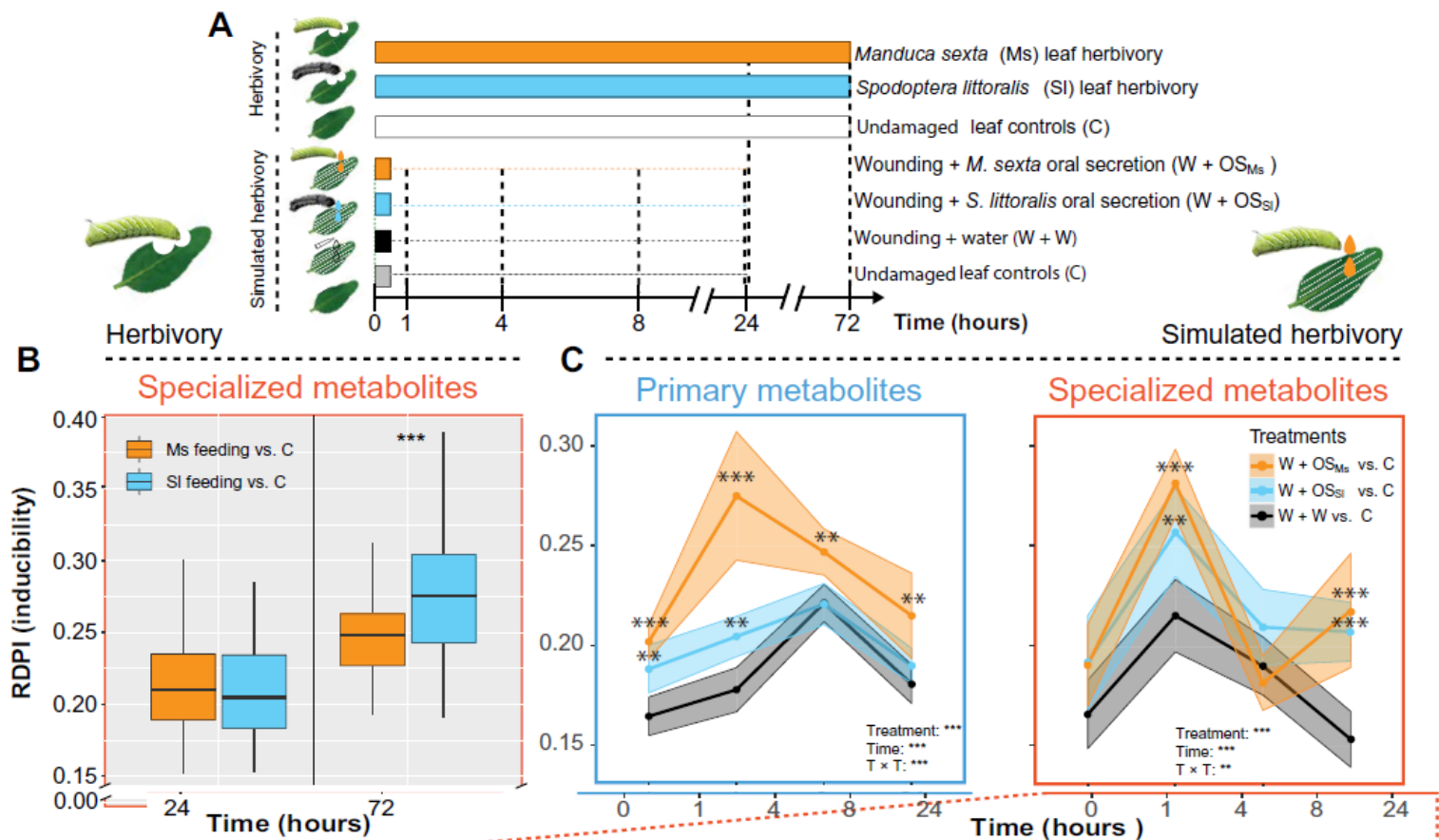


<https://www.gardenerdirect.com/dr-nikki-sawyers-science-corner/2017/july/alkaloids/>

Keemiline mälu



Nicotiana attenuata



SCIENCE ADVANCES | RESEARCH ARTICLE

PLANT SCIENCES

Information theory tests critical predictions of plant defense theory for specialized metabolism

Dapeng Li¹, Rayko Halitschke¹, Ian T. Baldwin^{1*}, Emmanuel Gaquerel^{2,3*}

Li et al., *Sci. Adv.* 2020; **6**: eaaz0381 10 June 2020

Loengukava

Stress ja taimed. Kohanemine ja stressimälu

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Pärilik, põlvkondadevaheline mälu

Taimedel võib teatud juhtudel säiluda DNA metülatsoonimuster gametogeneesis (sugurakkude teke)

Five degrees of methylation



<https://www.cell.com/current-biology/pdf/S0960-9822%2899%2980490-4.pdf>

H. käokannus (*Linaria vulgaris*): peloria mutant, kirjeldatud Carl Linne poolt 1744 aastal.

Pärilik õite erinev kuju on põhjustatud DNA metüleerimisest

Biochemical and Biophysical Research Communications 573 (2021) 112–116



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Biochemical and Biophysical Research Communications

journal homepage: www.elsevier.com/locate/ybbrc

Increased CG, CHG and CHH methylation at the *cycloidea* gene in the “Peloria” mutant of *Linaria vulgaris*

Ann E. Ehrenhofer-Murray*



The Linnaean Gardens of Uppsala

Uppsala University / The Linnaean Gardens ... / Learning / Linnaeus Online 2019 / Plants and animals / The order in ... / *Peloria* – a monster

Linnaeus Online 2019

The life of Linnaeus

Linnaeus and pharmacy

Plants and animals

The order in nature

Systema Naturae – an
epoch-making book

Systematics – order
through relationship

Cladistics reveal the tree
of life

DNA reveals relationships

A system for all living

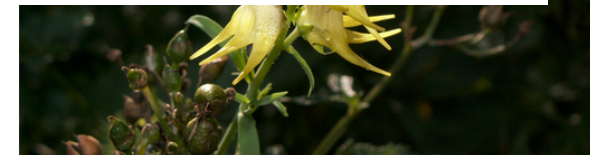
Peloria – a monster

Common toadflax, *Linaria vulgaris*, has a two-lipped flower with a spur. It has four stamens, of



Meeting *Peloria* Linnaeus had to consider that a species might not be as stable as he had thought.

... and has five spurs and five stamens of equal length, and was placed in a different class, the Pentandria.



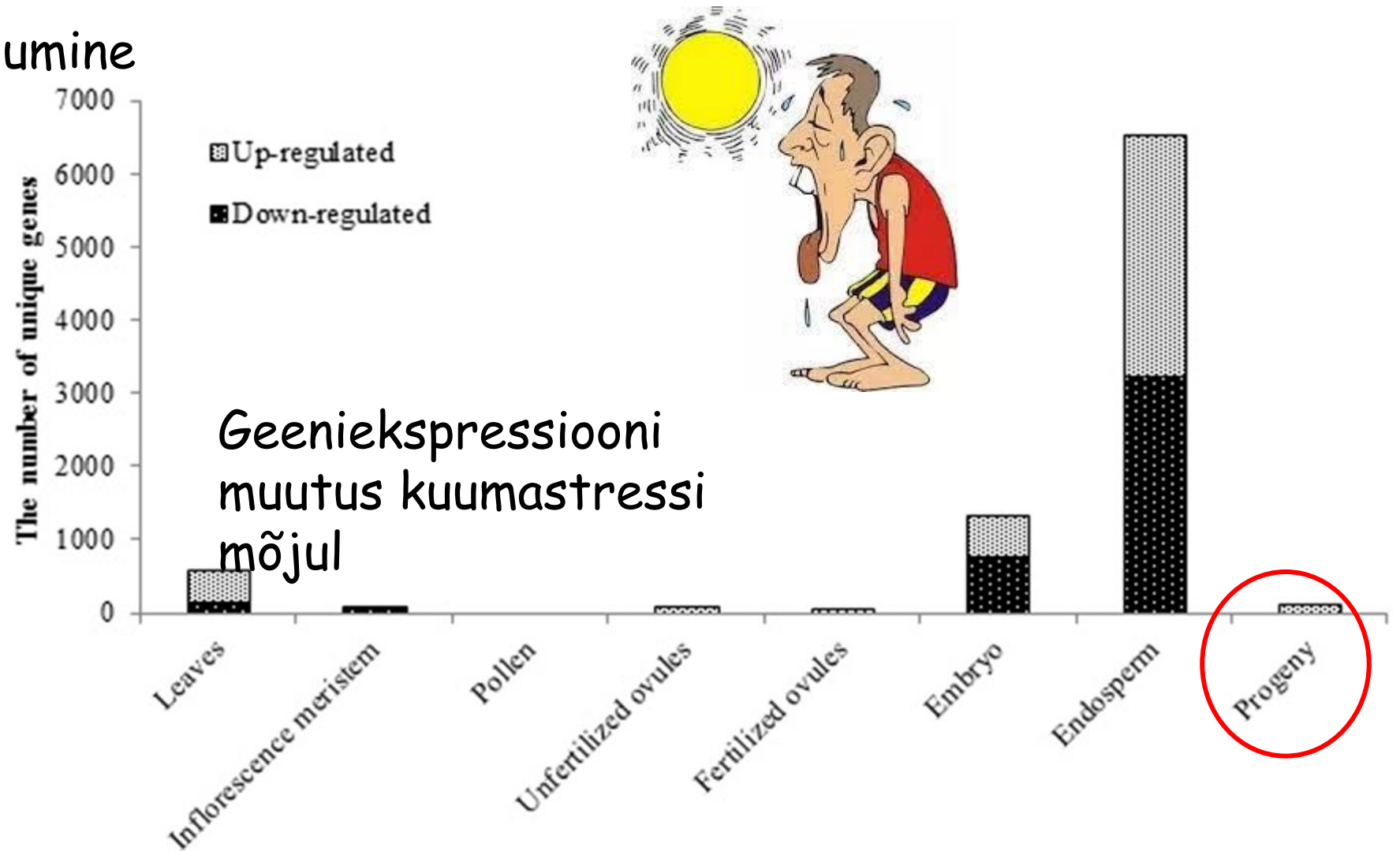
Peloria is a mutation of the common toadflax.

How could the stamens differ so much between two otherwise very similar plants? Linnaeus at last suggested that *Peloria* was a hybrid between common toadflax and some other, unknown, plant. If the seeds of this hybrid could germinate and grow into new *Peloria*-plants one would have had to draw the conclusion that new species could originate in nature.

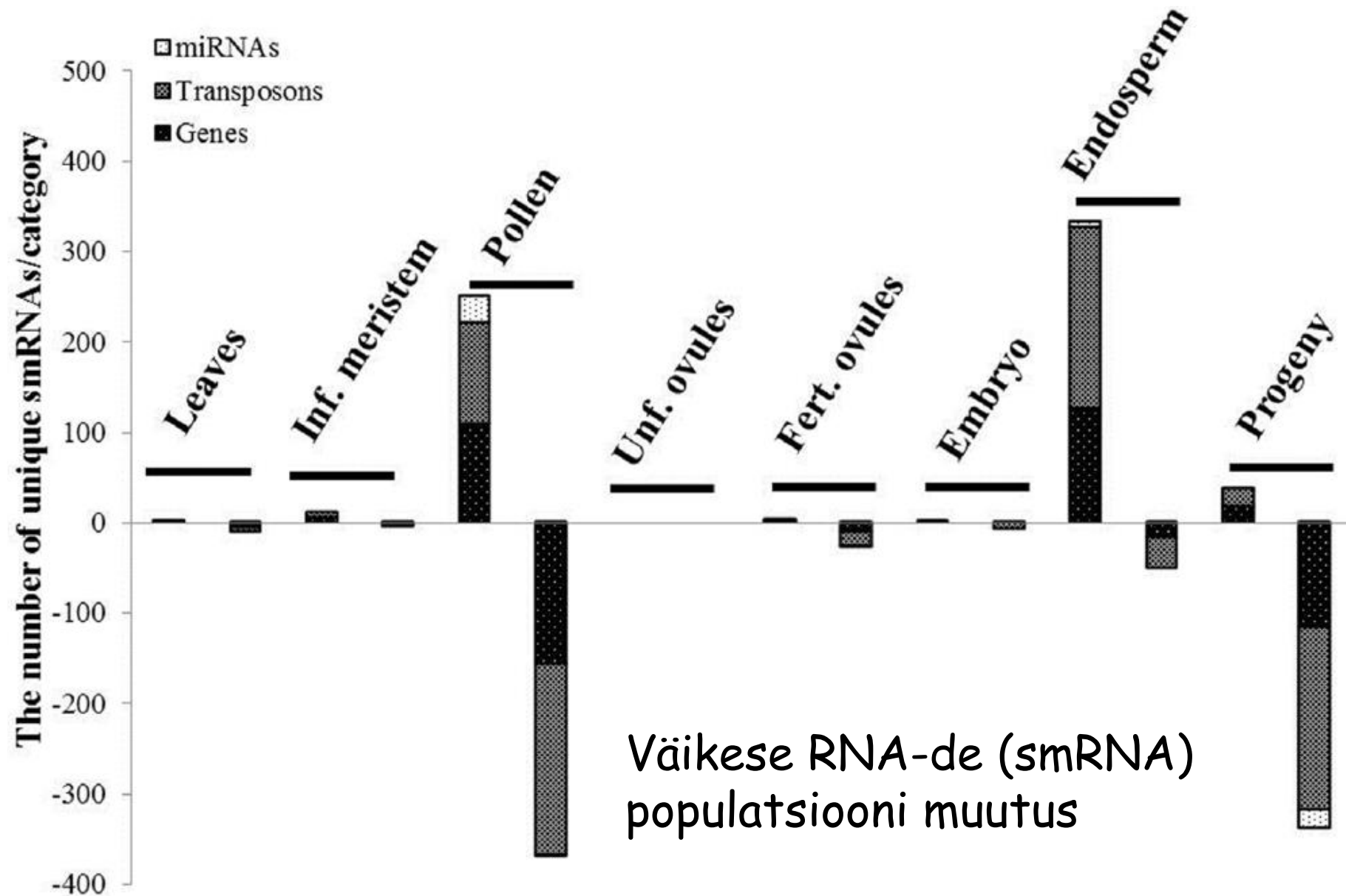
Stressimälu pärandumine



Naeris (*Brassica rapa*)

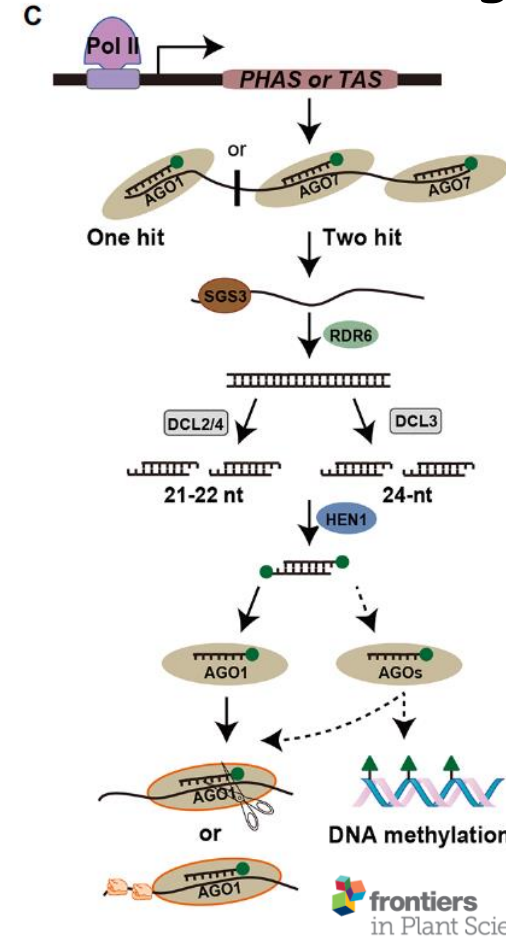
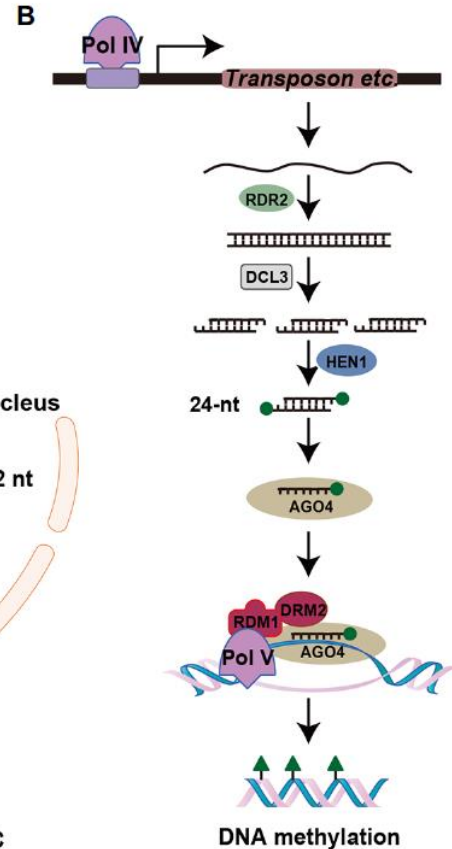
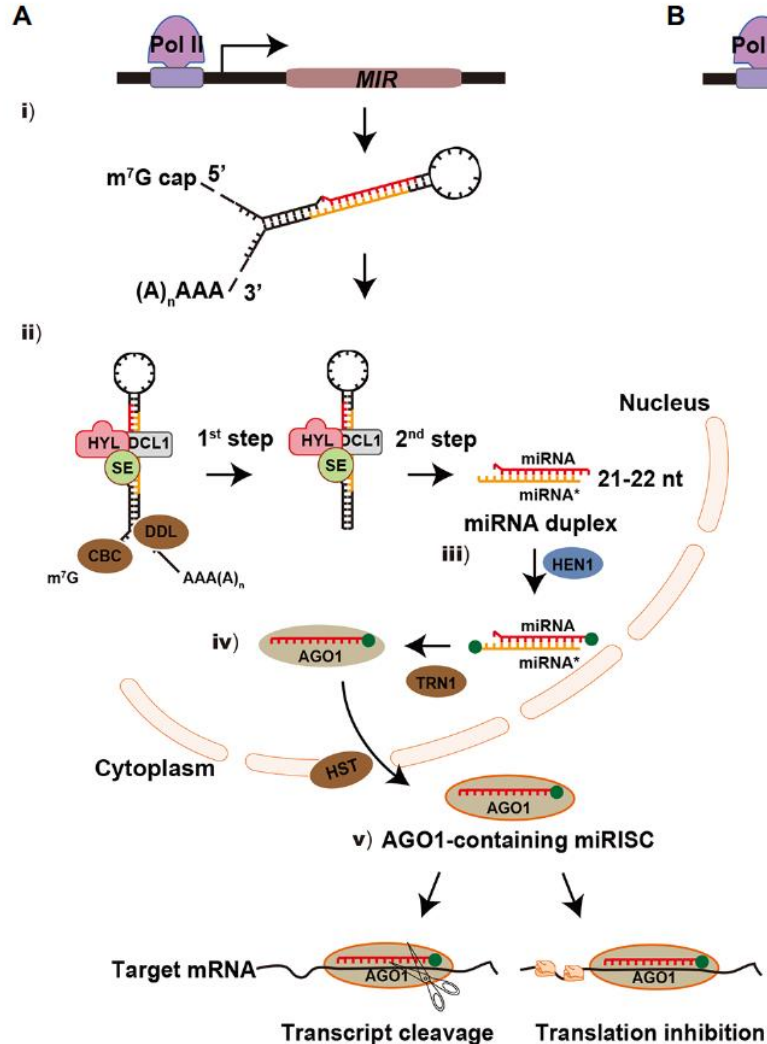


The elucidation of stress memory inheritance in *Brassica rapa* plants



Väikesed mittekodeerivad RNA-d

miRNA (mikro-RNA) siRNA (väike sekkuv RNA, vaigistav RNA)



Small RNAs: The Essential Regulators in Plant Thermotolerance

Zhi-Fang Zuo^{1,2}, Wenbo He¹, Jing Li¹, Beixin Mo¹ and Lin Liu^{1*}

REVIEW
published: 17 September 2021
doi: 10.3389/fpls.2021.726762

Loengukava

Stress ja taimed. Kohanemine ja stressimälu

Kuidas tekib stressimälu?

Pärilik, põlvkondadevaheline mälu

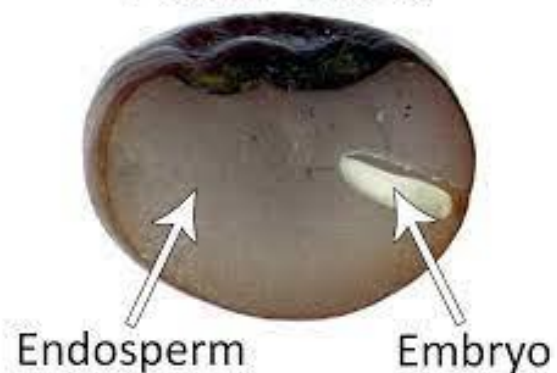
Emaliini mälu

Unustamise tähtsus

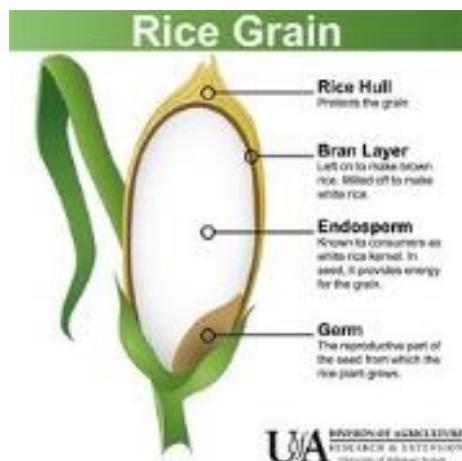
Kas kõik taimed käituvad ühtemoodi?

Emaliinipidi mälu pärandumine

Palm seed



Stress: väiksem seeme, vähem endospermi → väiksem taim, konkurentsivõime allajääv?



<https://www.gardeningknowhow.com/garden-how-to/propagation/seeds/thinning-seedlings.htm>

ORIGINAL ARTICLE

WILEY

Evolutionary Applications

Open Access

Egg size and the adaptive capacity of early life history traits in Chinook salmon (*Oncorhynchus tshawytscha*)

Michael W. Thorn  | Yolanda E. Morbey



Suurem munarakk: konkurentsieelis

Inimestel: madal sünnikaal seotud kõrgema südame-veresoonkonna haiguste riskiga

Auguste riskiga

	Birthweight category (kg)					P for linear trend
	<2.5	2.5-3.15	3.16-3.82	3.83-4.5	>4.5	
CHD						
Men						
Cases	283	1191	2307	841	394	-
Crude incidence, per 1000 person years	12.40	10.85	10.10	9.86	11.88	-
HR (95% CI) in age-adjusted models *	1.21 (1.07 to 1.37)	1.07 (1.00 to 1.15)	1 [Reference]	0.94 (0.87 to 1.01)	0.95 (0.85 to 1.05)	<0.001
HR (95% CI) in multivariable models †	1.17 (1.04 to 1.33)	1.08 (1.01 to 1.16)	1 [Reference]	0.91 (0.84 to 0.98)	0.91 (0.82 to 1.01)	<0.001
Women						
Cases	852	2307	3045	744	162	-
Crude incidence, per 1000 person years	2.37	2.08	1.84	1.87	2.20	-
HR (95% CI) in age-adjusted models *	1.31 (1.21 to 1.41)	1.14 (1.08 to 1.20)	1 [Reference]	0.95 (0.88 to 1.03)	1.01 (0.86 to 1.19)	<0.001
HR (95% CI) in multivariable models †	1.27 (1.18 to 1.37)	1.16 (1.09 to 1.22)	1 [Reference]	0.92 (0.85 to 1.00)	0.92 (0.78 to 1.07)	<0.001

Associations of birth weight and later life lifestyle factors with risk of cardiovascular disease in the USA: A prospective cohort study

Yi-Xin Wang,^{a*} Yanping Li,^a Janet W. Rich-Edwards,^{b,c} Andrea A. Florio,^a Zhilei Shan,^d Siwen Wang,^a JoAnn E. Manson,^{b,e,f} Kenneth J. Mukamal,^g Eric B. Rimm,^{a,b,d} and Jorge E. Chavarro^{a,b,e}

Loengukava

Stress ja taimed. Kohanemine ja stressimälu

Kuidas tekib stressimälu?

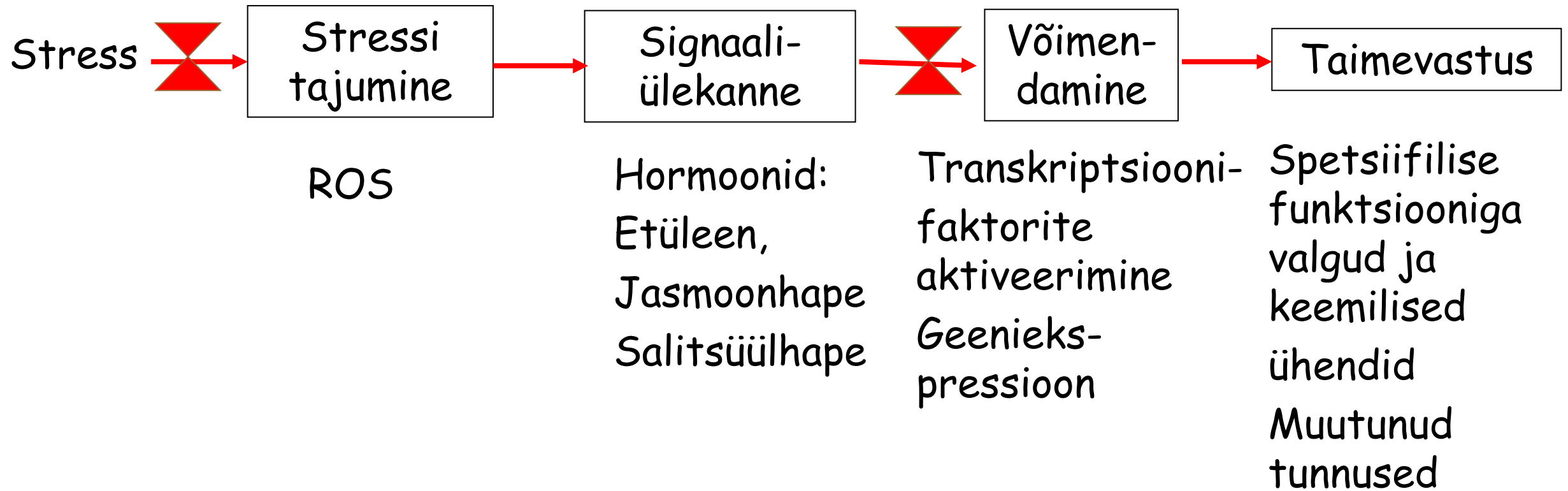
Pärilik, põlvkondadevaheline mälu

Emaliini mälu

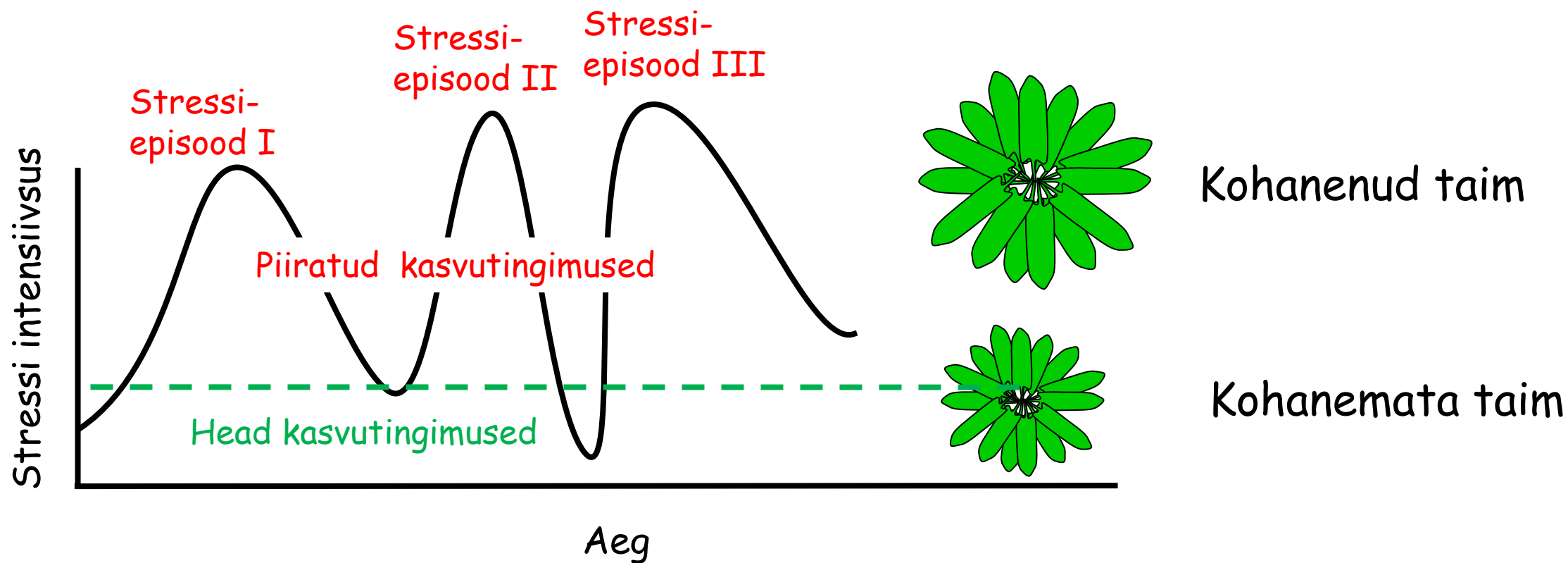
Unustamise tähtsus

Kas kõik taimed käituvad ühtemoodi?

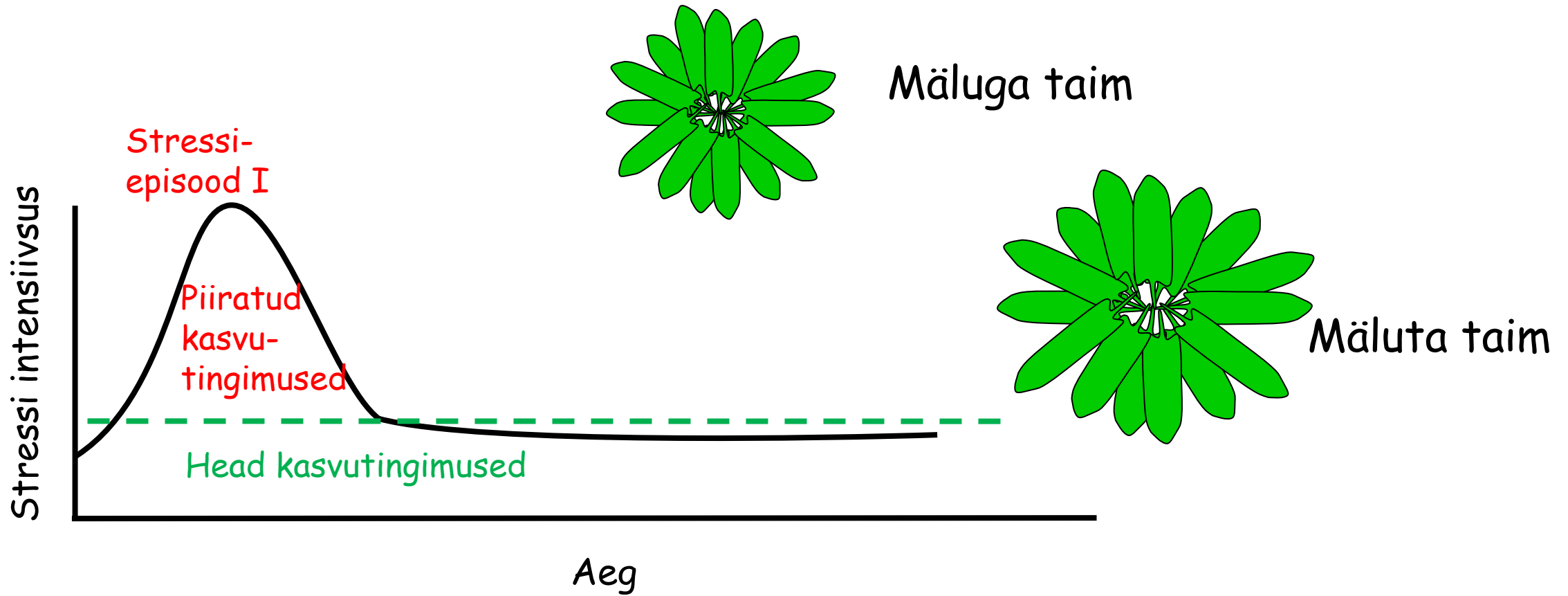
Stressivastus ja kohanemine



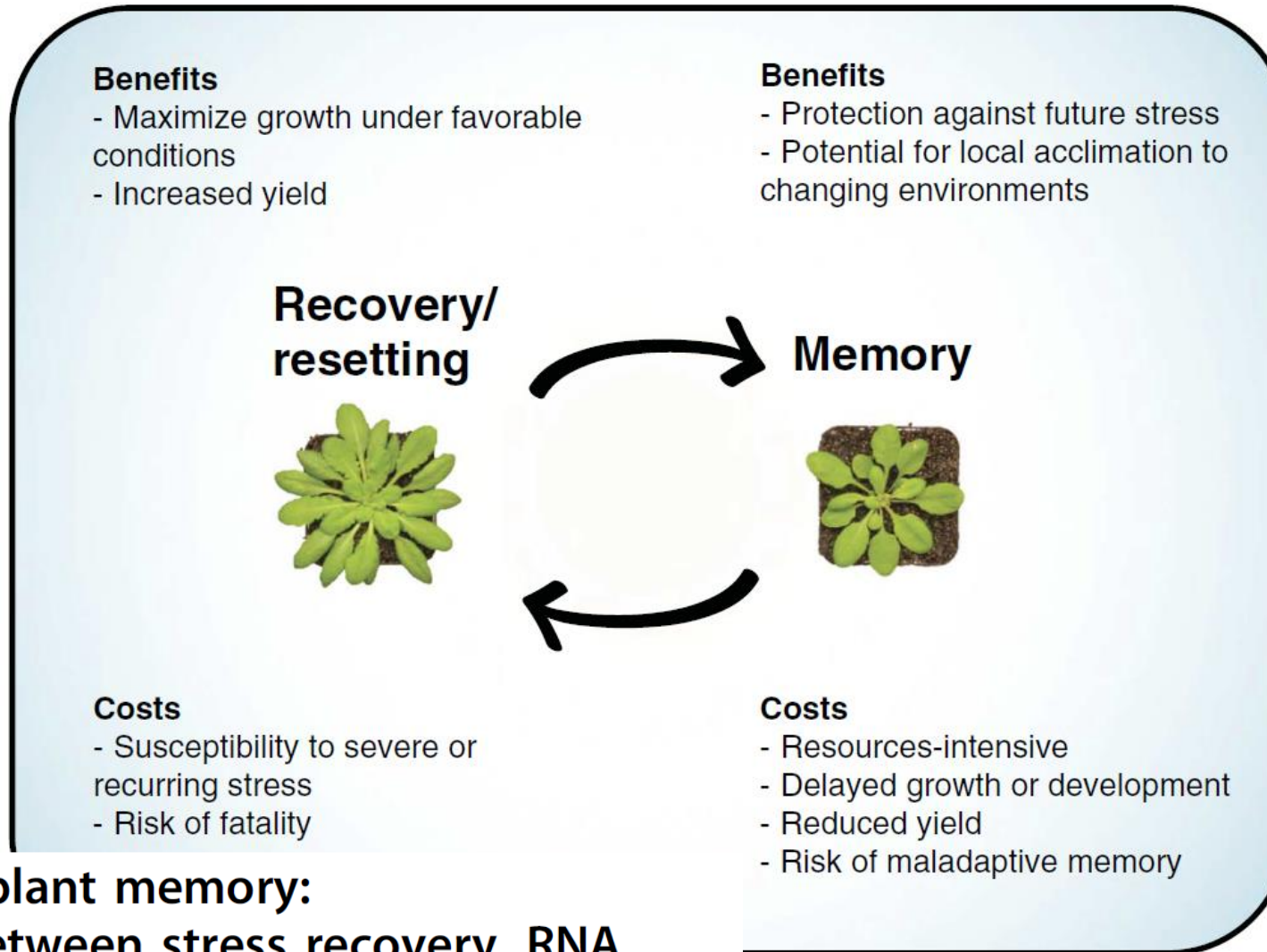
Mälu: kuna on kasulik unustada?



Mälu: kuna on kasulik unustada?



Kuna on kasulik unustada?



**Reconsidering plant memory:
Intersections between stress recovery, RNA
turnover, and epigenetics**

Loengukava

Stress ja taimed. Kohanemine ja stressimälu

Kuidas tekib stressimälu?

Pärilik, põlvkondadevaheline mälu

Emaliini mälu

Unustamise tähtsus

Kas kõik taimed käituvad ühtemoodi?

Valdav osa taimede mälualasest tööst on tehtud rihu-müürloogaga. Rihu-müürlook on väike üheaastane kiirekasvuline taim, mis reageerib kiiresti keskkonnatingimuste muutusele



Arabidopsis thaliana



June 2003

Thanks to the generous contribution of the
Banksia Foundation and the Banksia Foundation
for the use of the Banksia Foundation logo and the Banksia Foundation
in the Banksia Foundation logo.

BANKSIA FOUNDATION

Suur fotosünteesi kiirus
Kõrge plastilsus
Madal stressitolerantsus



Arabidopsis thaliana



Populus laurifolia



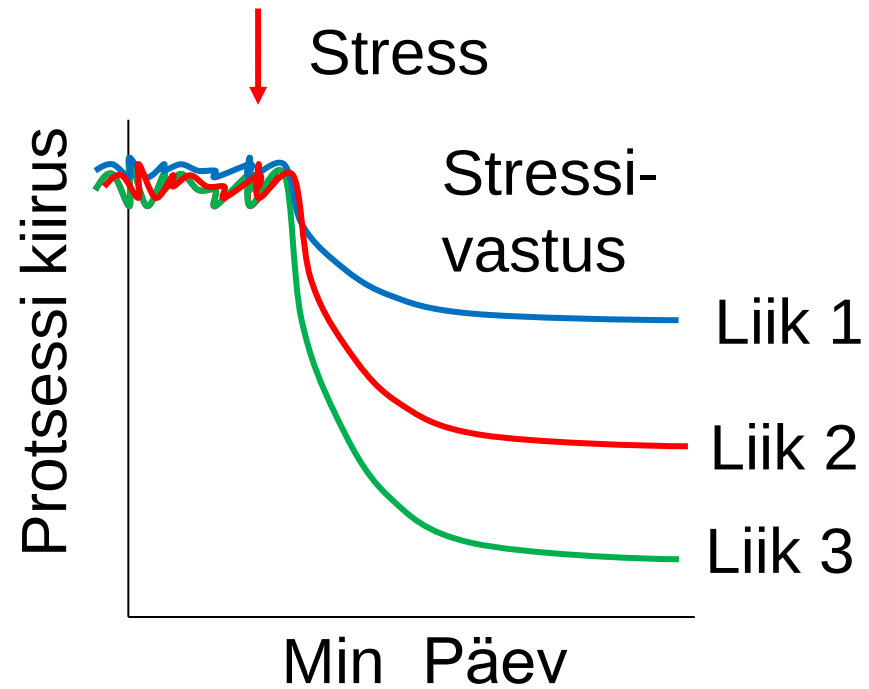
Quercus ilex

Kiire
Lehtede strateegia spekter
Aeglane

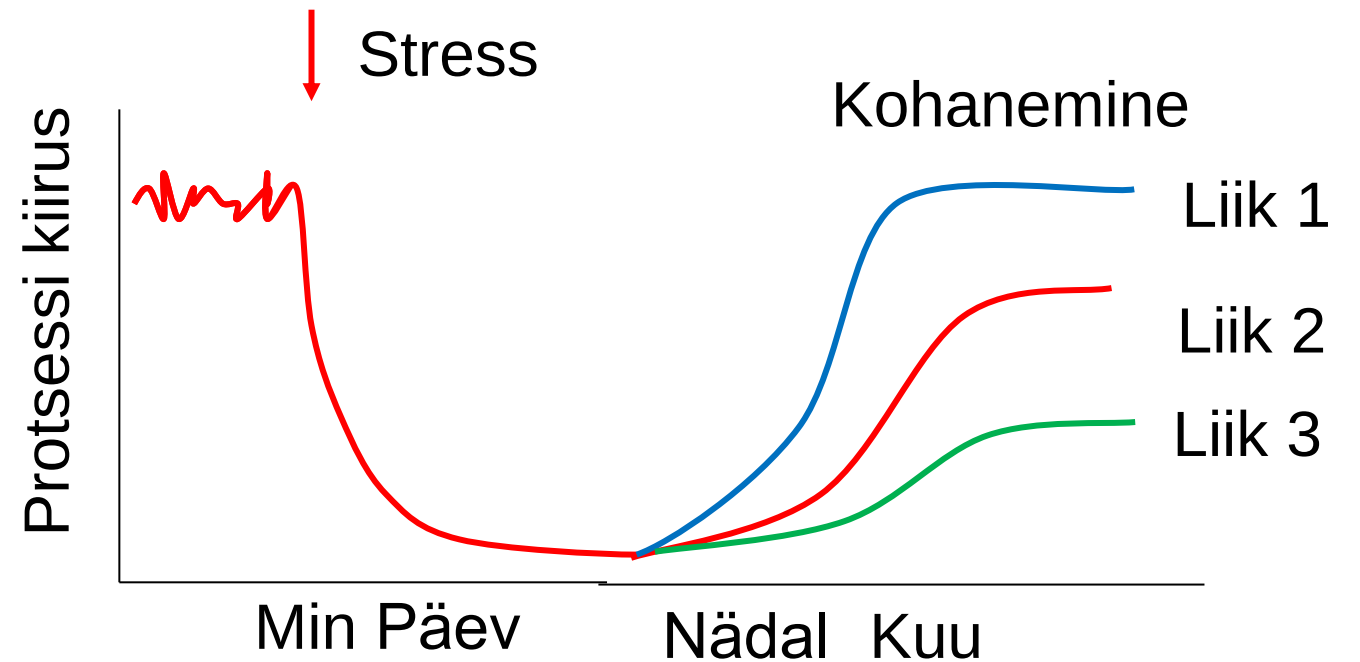
Väike fotosünteesi kiirus
Madal plastilsus
Kõrge stressitolerantsus

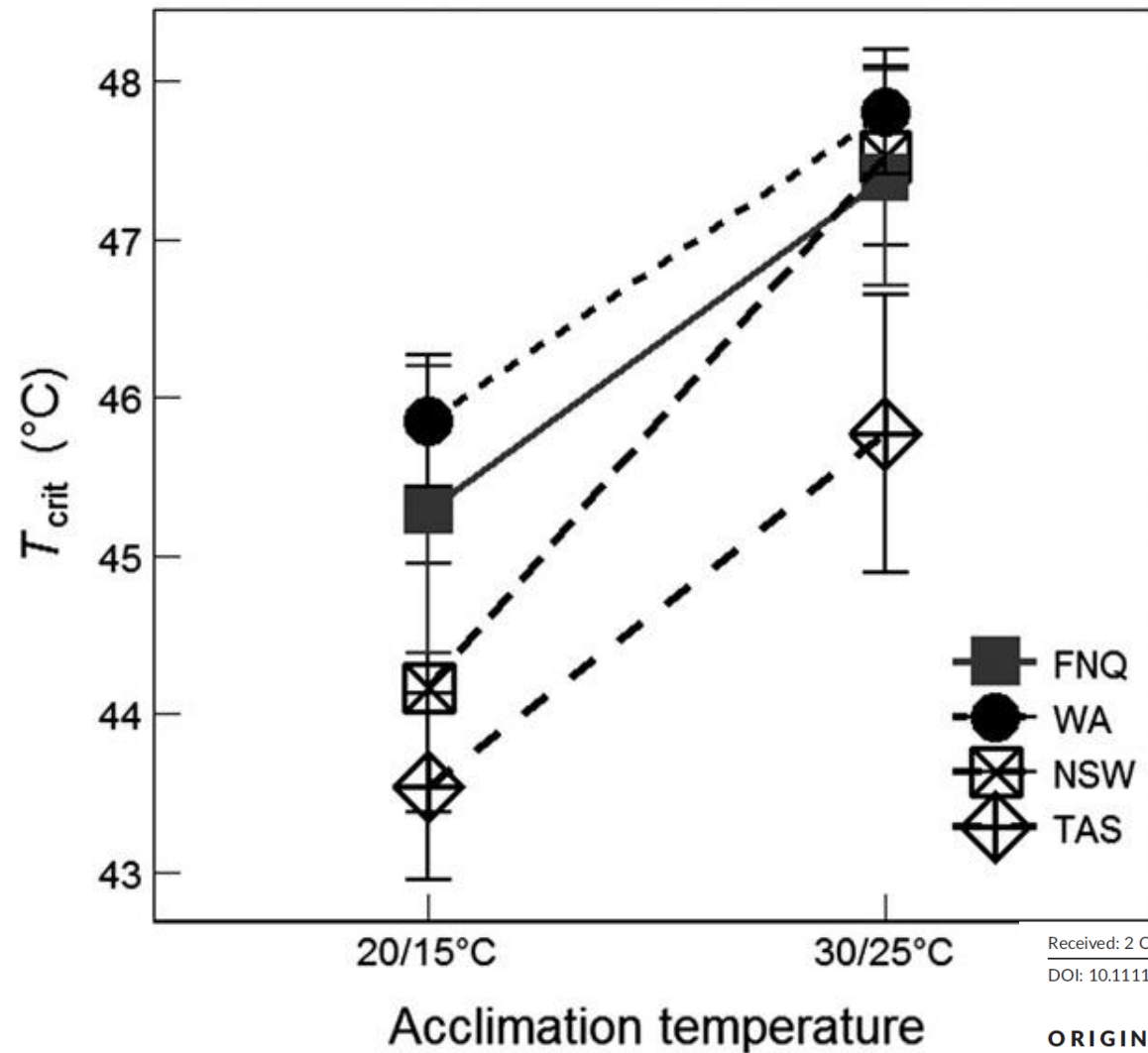
Liikidevahelised erinevused stressitaluvuses ja kohanemise määras

Erinevus stressitaluvuses



Erinevus kohanemise määras





Plant Cell Environ. 2018;41:1251–1262.

Received: 2 October 2017 | Revised: 18 December 2017 | Accepted: 18 December 2017
DOI: 10.1111/pce.13133

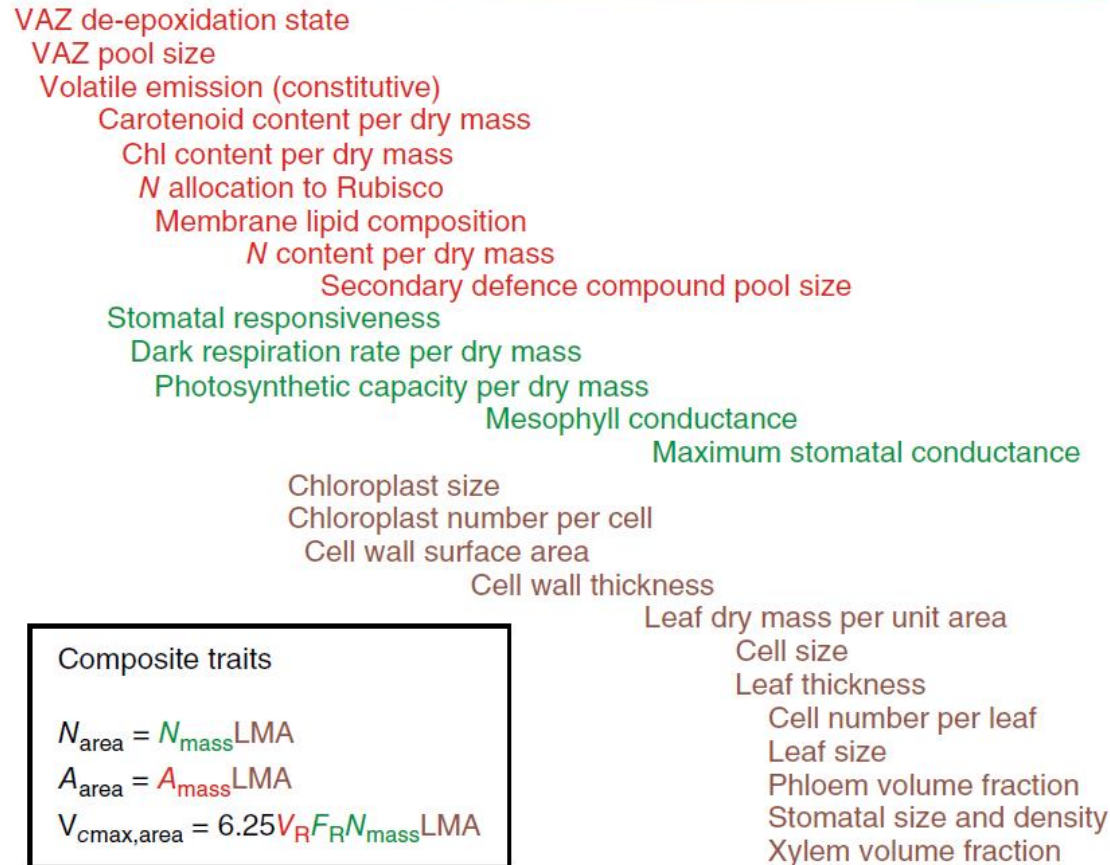
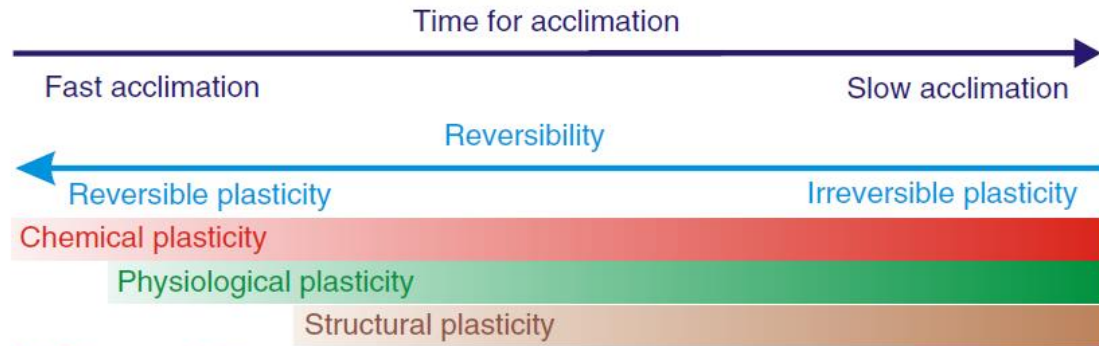
ORIGINAL ARTICLE

WILEY Plant, Cell & Environment

Plasticity of photosynthetic heat tolerance in plants adapted to thermally contrasting biomes

Lingling Zhu^{1,2} | Keith J. Bloomfield² | Charles H. Hocart² | John J.G. Egerton^{2,3} |
Odhran S. O'Sullivan² | Aurore Penillard² | Lasantha K. Weerasinghe^{2,4} | Owen K. Atkin^{1,2}

Kui kiiresti ja kui suurel määral toimub kohanemine eri taimeliikidel?



Annual Plant Reviews (2020) 3, 473–522
doi: 10.1002/9781119312994.apr0714

<http://onlinelibrary.wiley.com>



LEAF TRAIT PLASTICITY AND EVOLUTION IN DIFFERENT PLANT FUNCTIONAL TYPES

Ülo Niinemets^{1,2}

Mida mäletavad väga vanad taimed?



Igimänd: 4845
aastat

