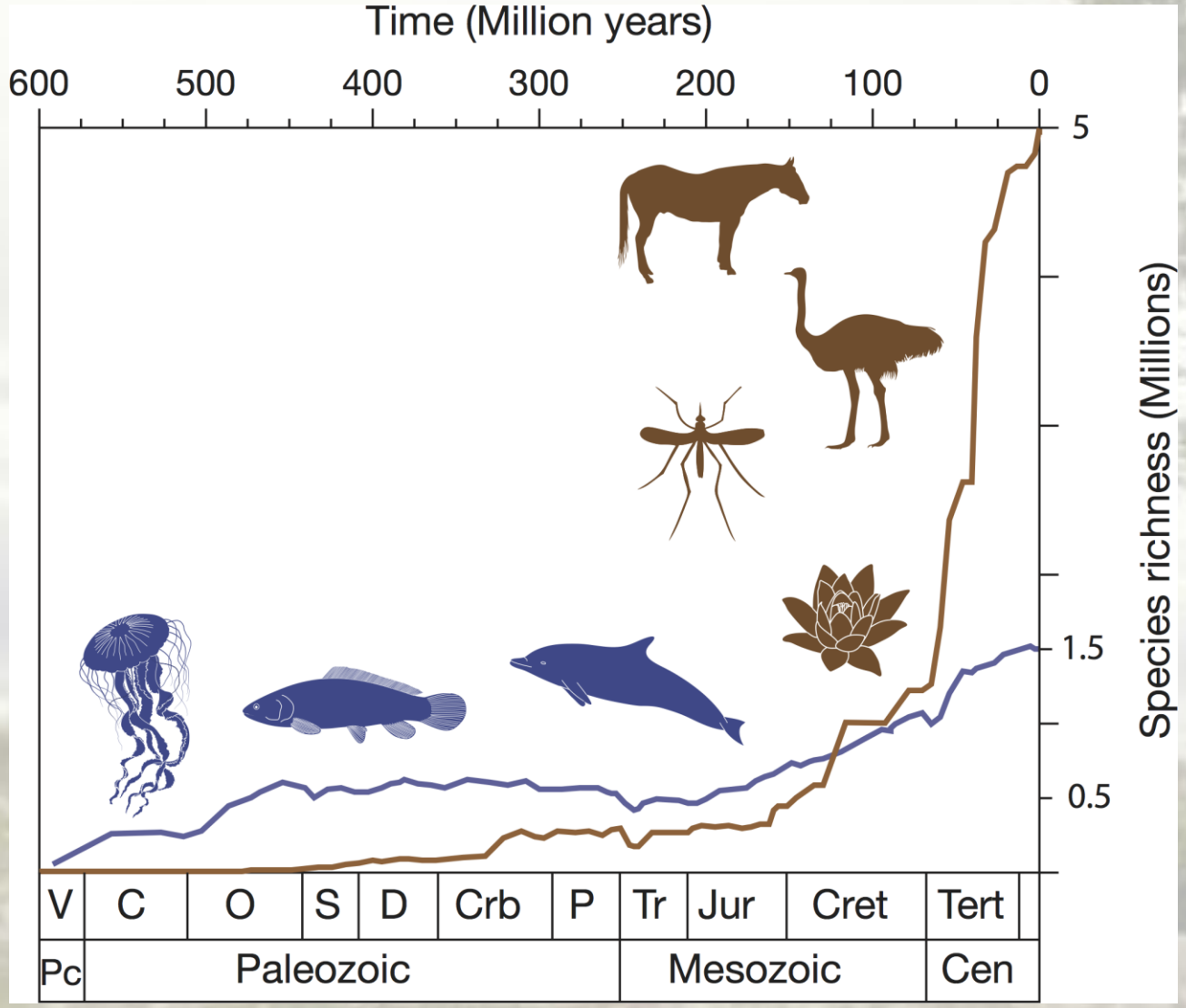
Plant Biodiversity and Evolution

- Prof. Giorgio Binelli
- DBSV – Università degli Studi dell'Insubria
- S.I.B.E.- I.S.E.B. Italian Society for Evolutionary Biology
- A.G.I. Italian Genetics Society

From Biodiversity to Diversification:
Resources, Tools and Technologies
to Meet New Challenges
ISTA Seminar Verona 29 May 2023

Flowering plants appeared relatively recently …



Benton MJ (2016) Origins of Biodiversity. PLoS Biol 14(11): e2000724

The first evidence of flowering plants is reported in the Early Cretaceous period.

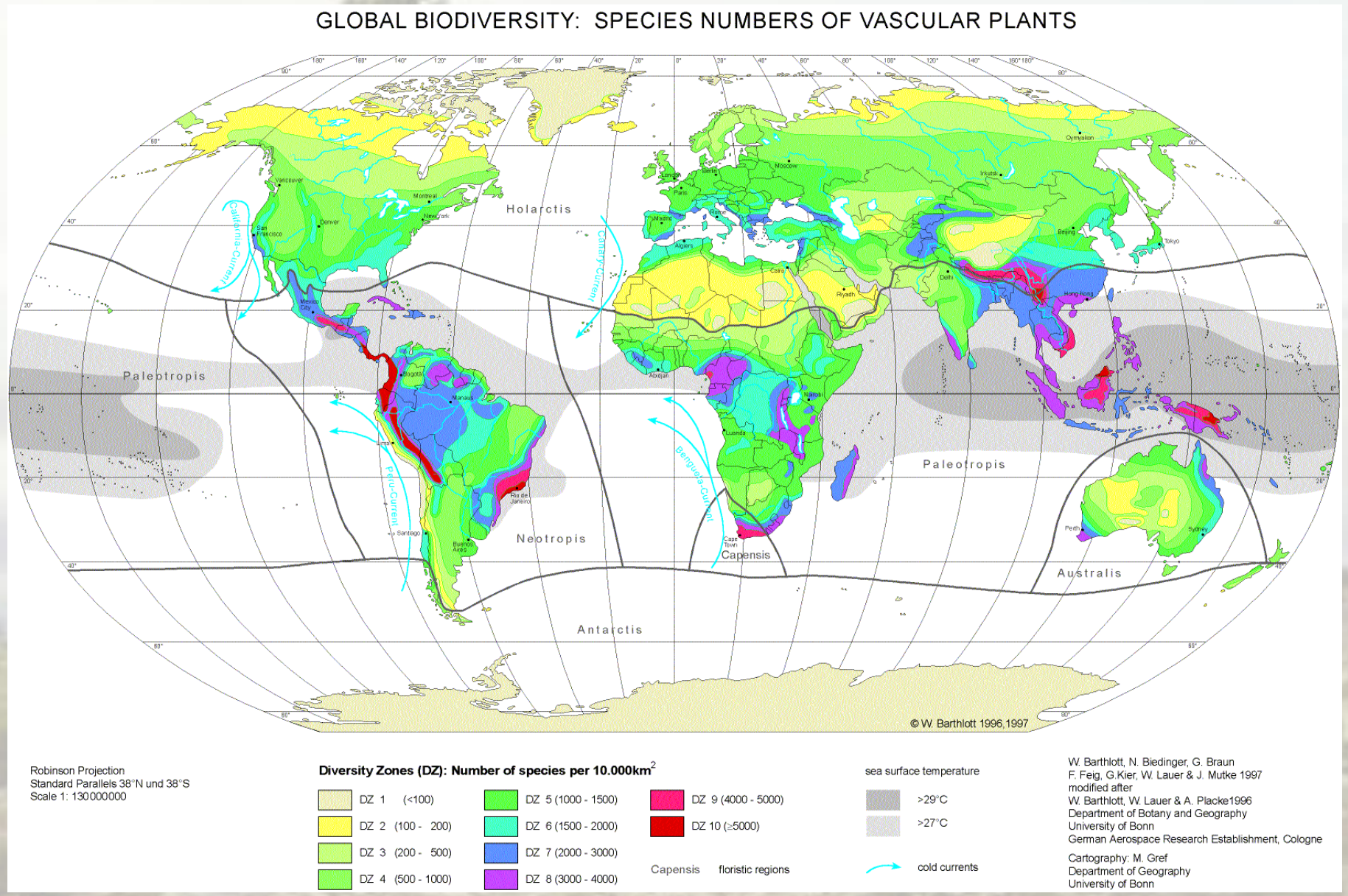
The emergence of flowering plants was a major evolutionary event.

The introduction of new reproductive strategies that allowed for more efficient pollination and seed dispersal led to their rapid spread and domination in terrestrial ecosystems and also to an impact on animal evolution.

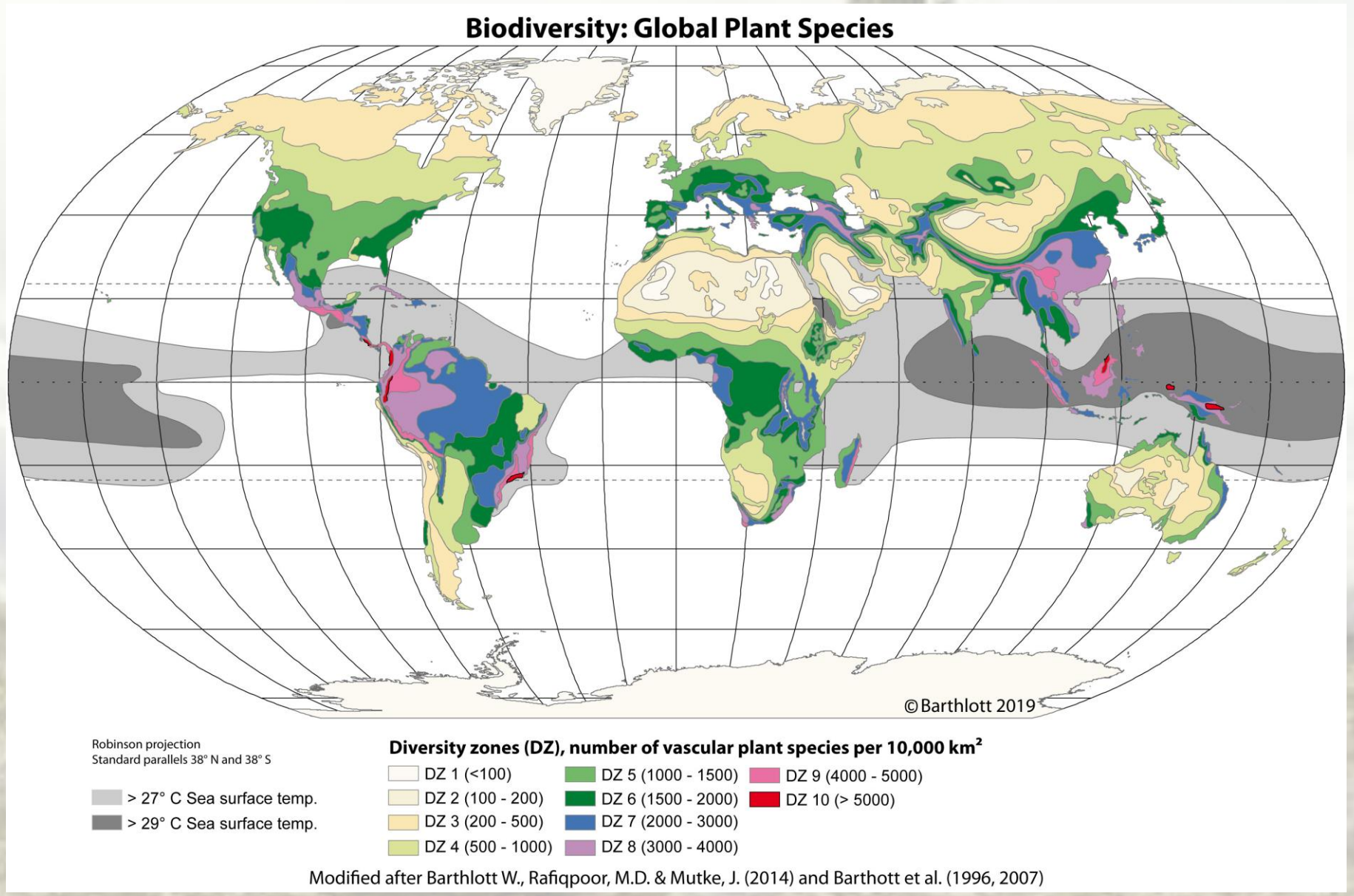
… but plants had great evolutionary success

Plant Biodiversity as assessed in 1997 shows how plants have colonized all kind of environments, with areas boasting more than 5,000 species per 10.000 km^2

However, what goes up can fall down.



Twenty years later



- In 2019, species diversity was severely reduced.
- This is especially evident in the Tropical and Neotropical regions.

About biodiversity

- Biodiversity is a core concept in biology and has been the subject of discussion since Biology was born.
- However, despite its importance, few generalities about biodiversity exist - probably, as ever in biology, laws are elusive because of the contingent nature of the properties and history of each species and larger group.
- As evolutionary biologist, I have always loved the definition:

"Nothing in Biology Makes Sense Except in the Light of Evolution*"

- but what is the relationship here?

*Theodosius Dobzhansky, 1973

Several «biodiversities» actually exist

Ecological Diversity	Genetic Diversity	Species Diversity
Biosphere		Kingdom
Ecozone		Phylum
Biome		Family
Ecosystem		Genus
Biotope	The components of biodiversity have something in common	Species
Niche		Subspecies
Population	Population	Population
	Individual	Individual
	Chromosome	
	Gene	
	Nucleotide	

Maybe that ...

Nothing in Biology Makes Sense Except in the Light of Population Genetics*?

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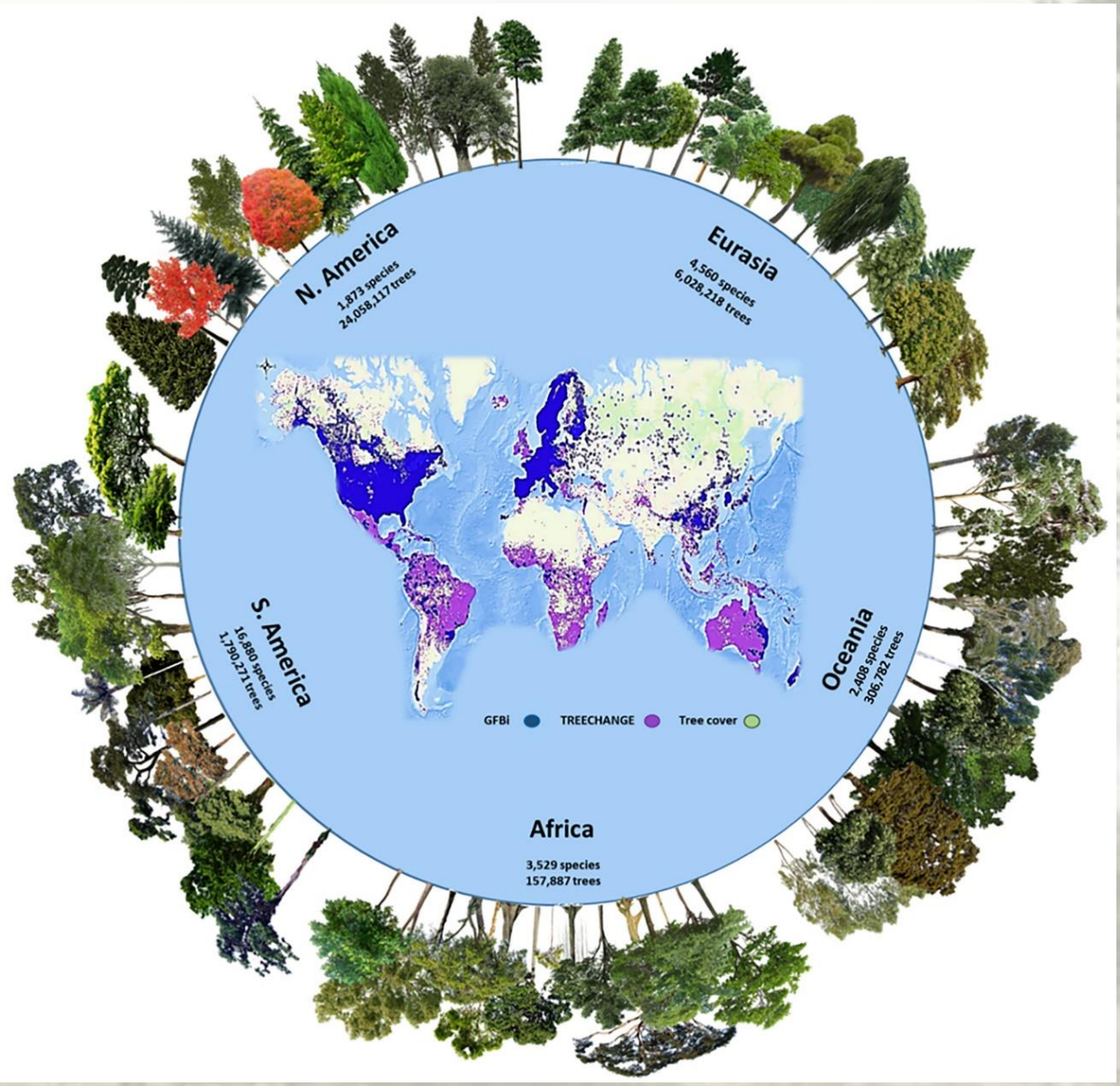
*and Population Genomics

How many trees?



Gatti *et al.*, doi: 10.1073/pnas.2115329119.

The number of tree species and individuals per continent was estimated by the Global Forest Biodiversity Initiative (GFBI) database (blue dots) merged with the TREECHANGE occurrence based data (purple dots). Image from:

GFBI database alone records ~38 million trees for 28,192 species

The joint estimate of the number of tree species is 73,300, out of which ~9,200 yet undiscovered, roughly divided by continent as follows:

South America ~ 40%

Eurasia ~ 20%

Africa ~ 15%

North America ~ 15%

Oceania ~ 10%

Trees

- To say that forest trees are important for their ecological resources, services and in general for biodiversity is today a truism. The current technologies for genomic analysis allow us to have unprecedented insights into the evolution of forest trees and have opened new avenues for research.
- Among these, one could cite the possibility to study in detail genetic adaptation (and phenotypic plasticity) and to do evolutionary modelling based on the assessment of thousands of genotypes and for a variety of ecological data.

The case of *Fagus sylvatica*

- The summers of 2018 and 2019 were extremely dry in Europe.
- As a consequence, around two-thirds of European beech trees (*Fagus sylvatica*) were damaged or killed by extreme drought.
- This problem was compounded by the fact that beech woods are home to over 6000 other species of animals and plants.

Theissinger et al. 2023; https://doi.org/10.1016/j.tig.2023.01.005

The case of *Fagus sylvatica*

- However, it was observed that severely damaged trees and healthy ones were very close in the same stands.
- The assembling of the beech genome showed that the genetic makeup of a tree, rather than its local environment, determines its level of drought resistance.
- In fact, 80 regions of the genome differed between healthy and damaged trees.
- Based on these findings, a genetic test is now available to select and reproduce trees that are better adapted to drought.

Photos: Ulrich Wasem, WSL

Genetics is important

- The most fascinating possible outcome is in my opinion the ability to bring together again population genetics and quantitative genetics to deepen our understanding of evolutionary processes. As example, the assessment of genetic variation in response to local ecological conditions could be a useful starting tool to determine adaptive variation in natural stands.

Genetics will become more important

- Small regions of the genomes have been analyzed to this purpose.
- Big data analysis will help providing us with whole genome-level information. This information will be relevant for

i. estimating neutral genetic diversity (population history);

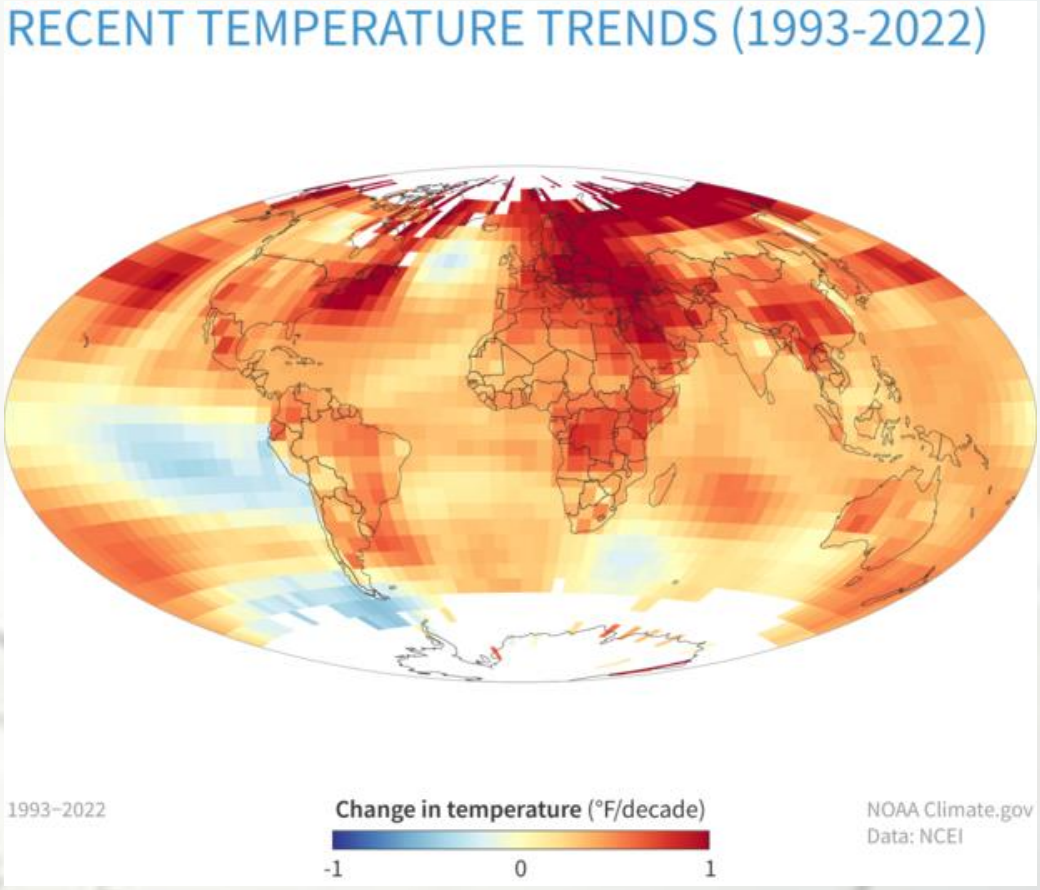
ii. detect signatures of selection;

iii. estimating recombination rates among different genomic regions, to assess the levels of linkage disequilibrium needed for QTL studies, variation in chromosome structure and so on.

- Besides, the knowledge of genetic adaptive traits is an essential support to actions in forest management and conservation, such as encouraging variety (cultivar) certification.

Applications

- The main field of application of this kind of studies will probably be in dealing with GCC, because information on the relationship between genetic variation and environmental variation is necessary to implement bioclimatic models to simulate how the present genetic variation will be shaped by a changing environment and to identify current and projected distribution of plant communities.

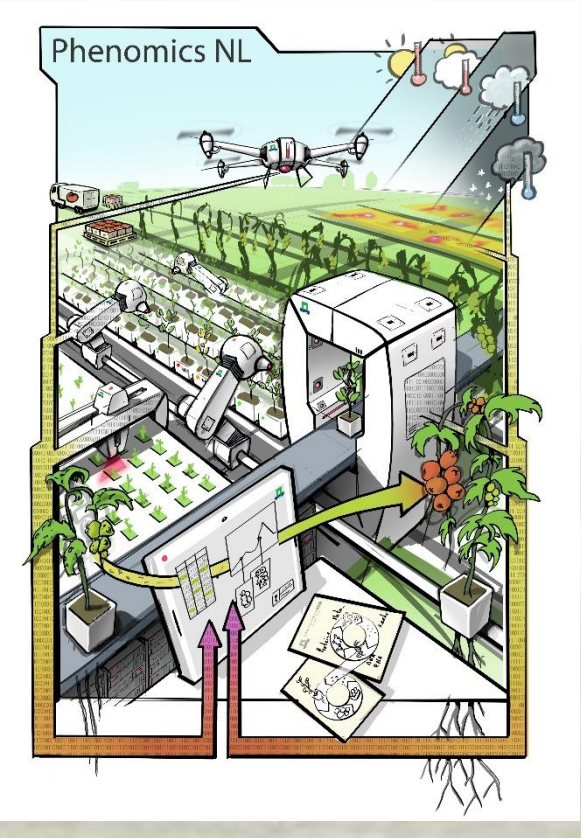


NOAA National Centers
for Environmental Information

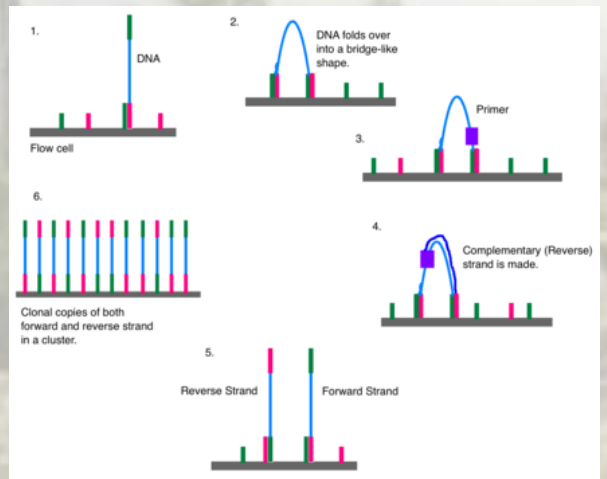
Applications (2)

- The information obtained from different approaches can lead to the identification of genotypes adapted to future climatic conditions, to select seed sources and populations for planning sound conservation strategies like assisted migration or assisted range expansion, to help forest tree species to cope with fast-changing climatic conditions and prevent localized declines.

Applications (3)



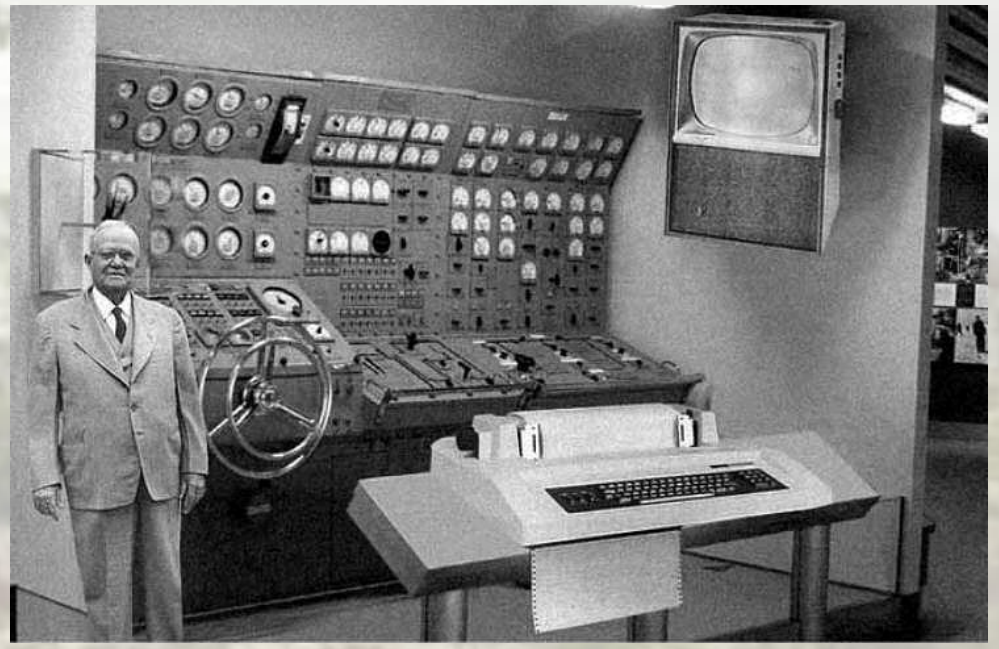
- To tap this almost infinite source of information, genetic, phenotypic and ecological, life scientists also need to understand and exploit the data and information from genomic, proteomic, phenotypic datasets that are increasingly growing in size.



Big Data & Data Science

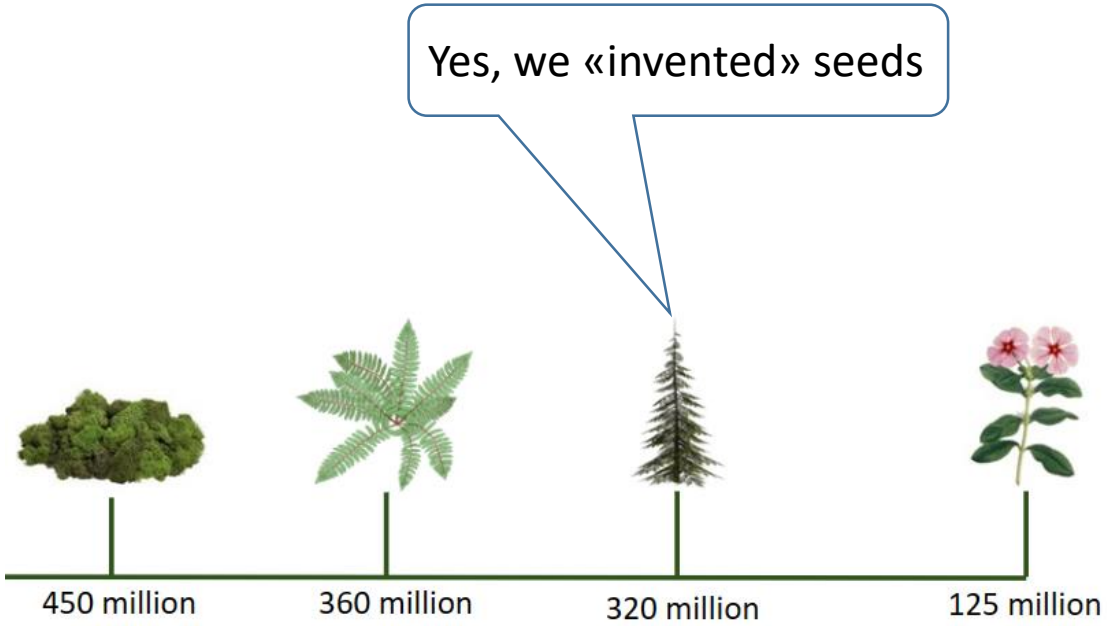
- Among these, paramount will be the attention devoted to computational methods - algorithms and data structures - for analyzing DNA sequencing data, SNP genotyping, epigenetic patterns and so on and to mathematical modelling, especially Bayesian, applied to evolutionary and ecological issues.

Do we need a generation of bioinformaticians?



Spruce Gran picea #0909-11A07 (9,550 years old, Sweden)

By the way, the annoying background of my slides is the oldest living tree.



Thank you for your attention!

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