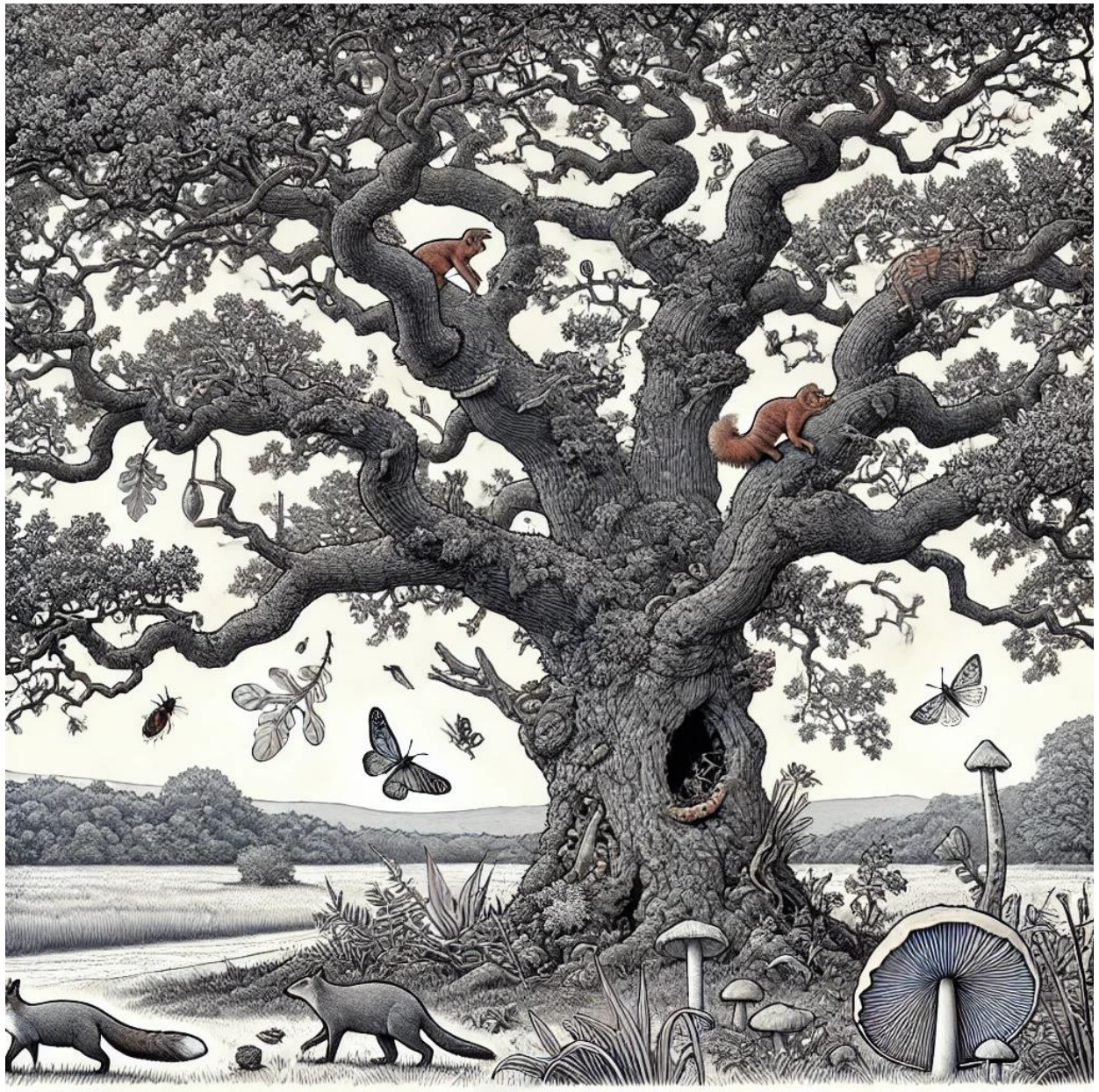

Beyond
woodlands and
Urban
Forests
Garden

Overview

- Tree Ecology
- Organisation of knowledge
  - Scale
  - Form & Function
    - the tree habit
    - growth & development
    - phytobiome
  - Application
- Stimulate thoughts on open grown trees and their management…

Oekologie

- Ernst Haeckel (1834-1919), coined the term which translates to "ecology" in English, to describe the study of how organisms interact with their environment.

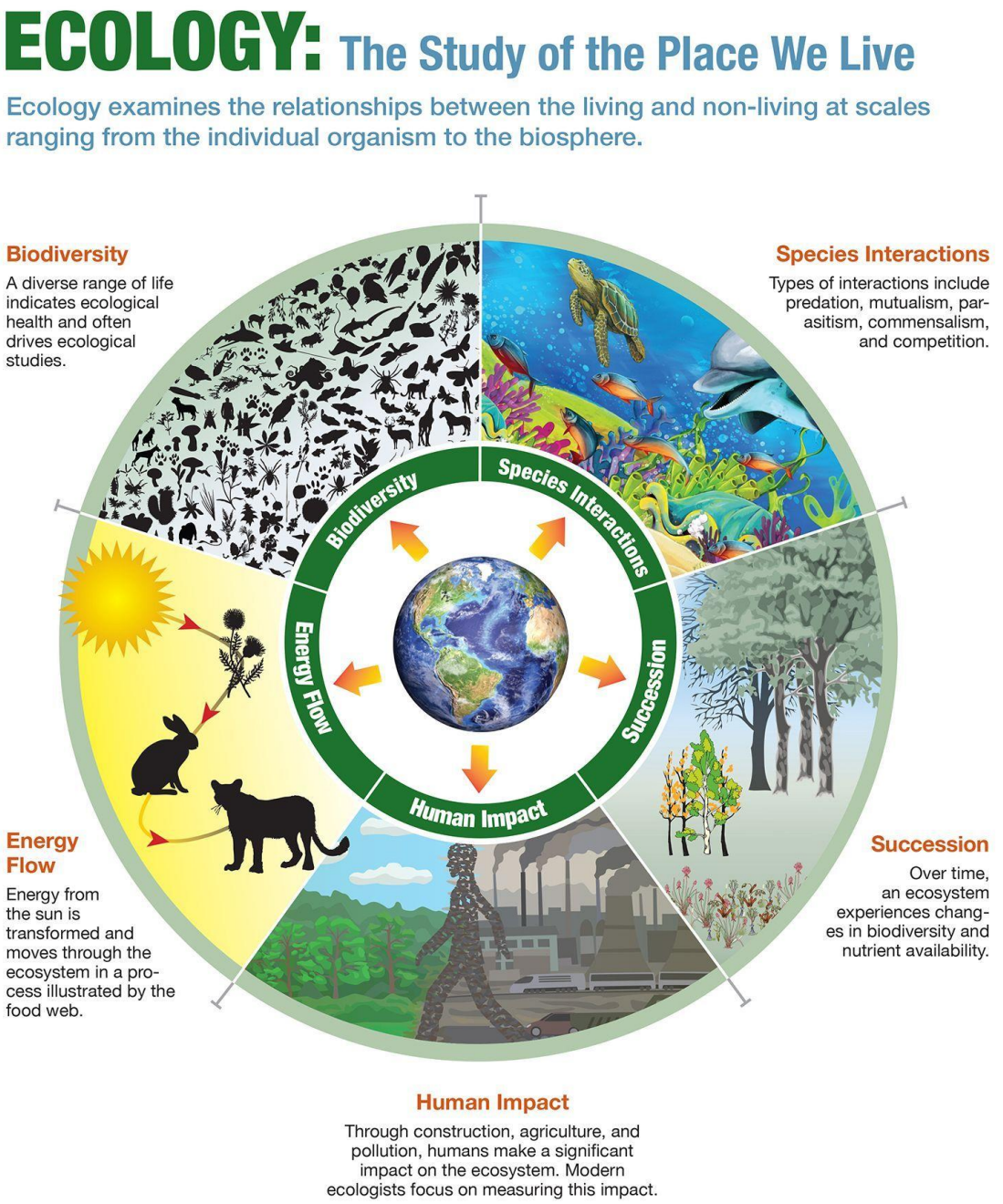


Ecology

The study of organisms:

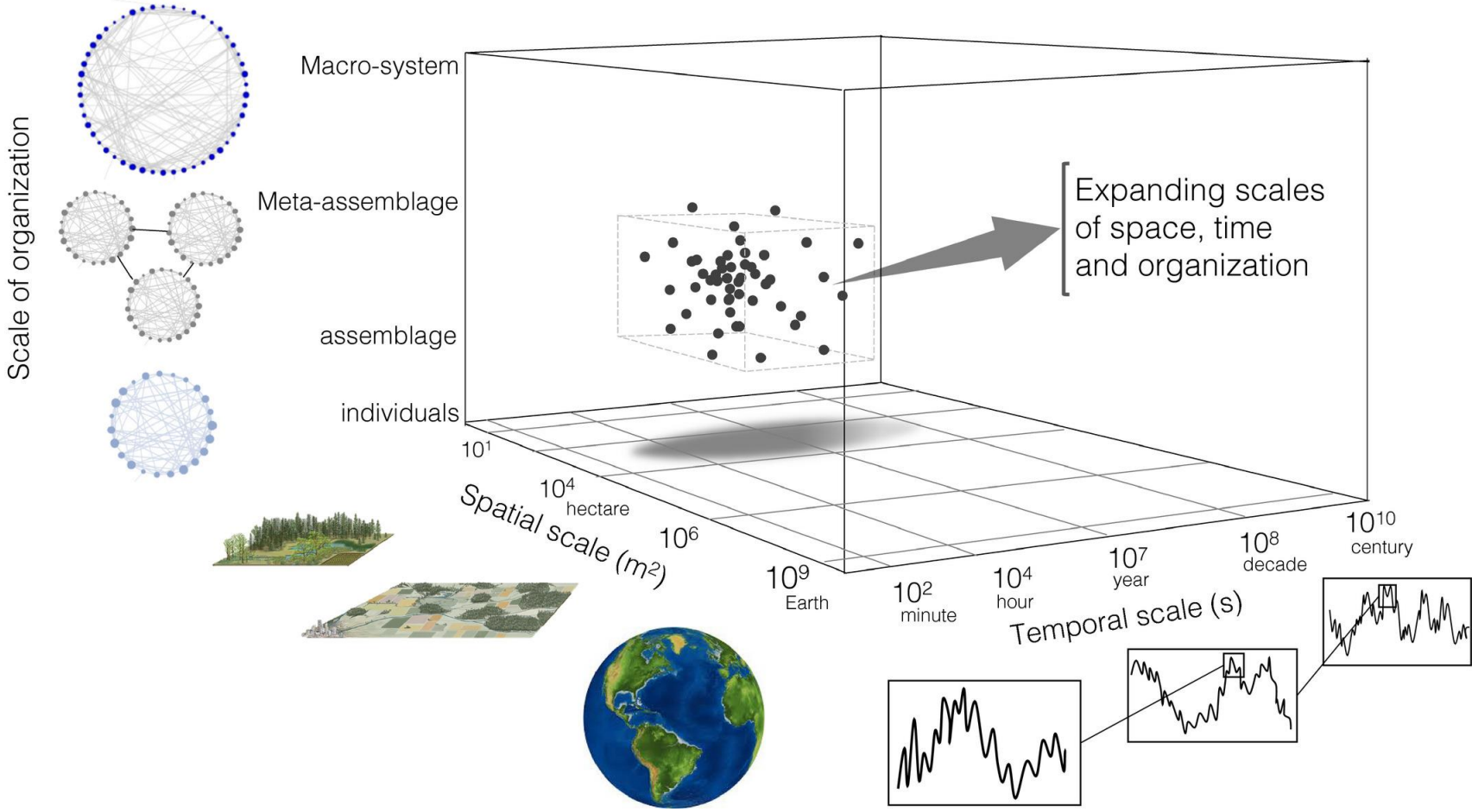
- distribution,
- abundance and
- dynamics

Including, their interactions with other organisms and with their physical environment.



Complex subject

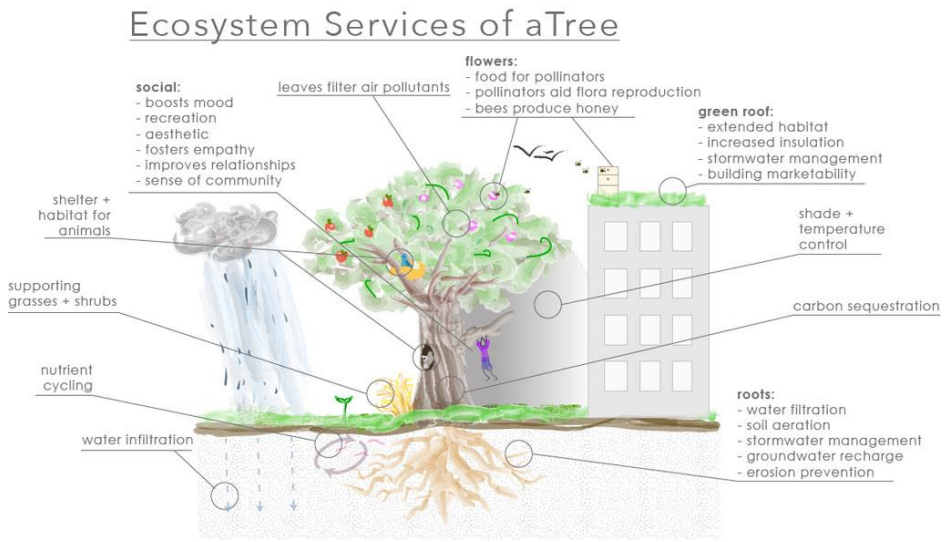
Ecology operates at a number of scales



The lack of biodiversity-ecosystem functioning studies done at larger scales as shown in the figure – source Gonzalez et al. (2020) https://doi.org/10.1111/ele.13456

Tree ecology

- The study of how trees interact with each other and with the environment.



Tree ecosystems

- Trees are ecosystems because they contain living and non-living parts that interact. Include the tree's roots, trunk, branches, and leaves plus soil and climate and necromass (deadwood).

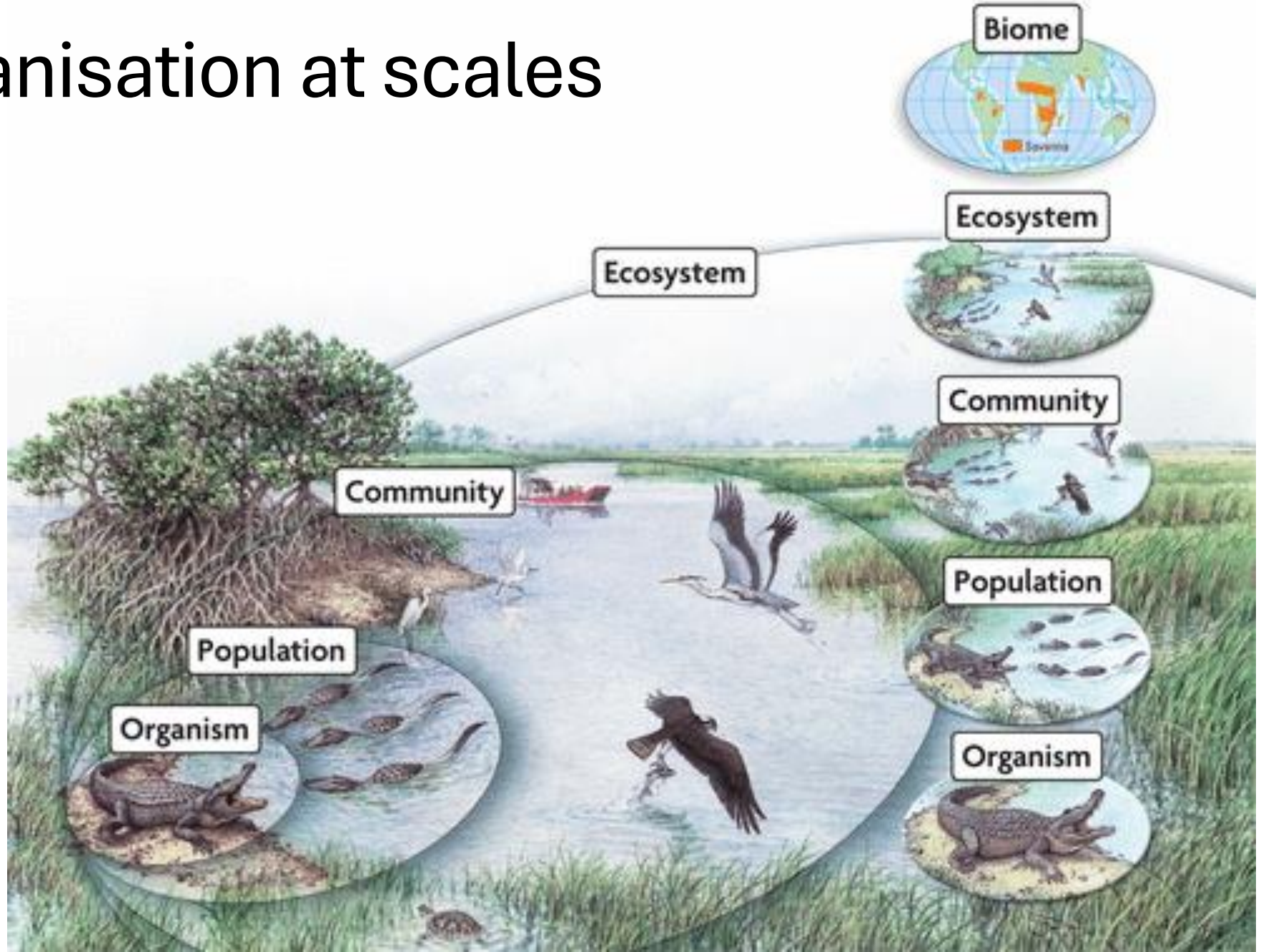
Tree microclimates

- Trees create microclimates and micro-environments for other organisms

Tree interdependence

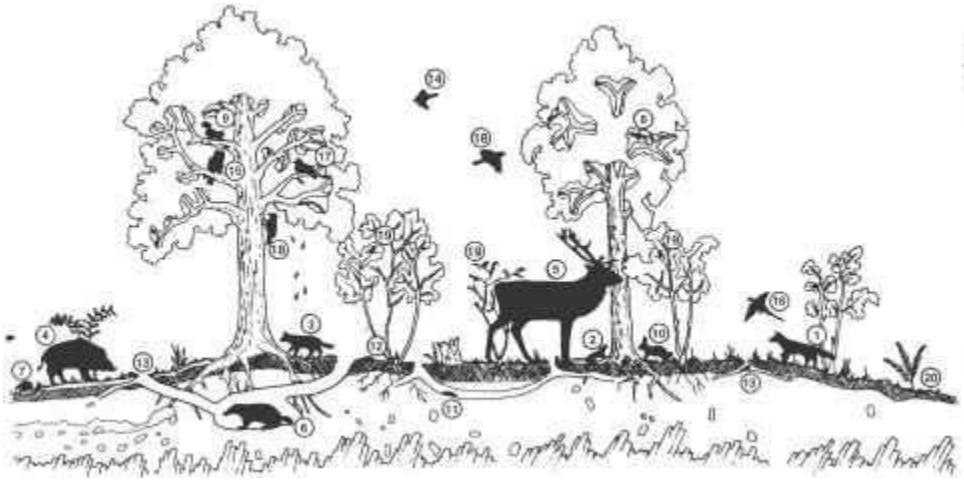
- Trees are often interdependent with other organisms, such as insects, fungi, and other plants.

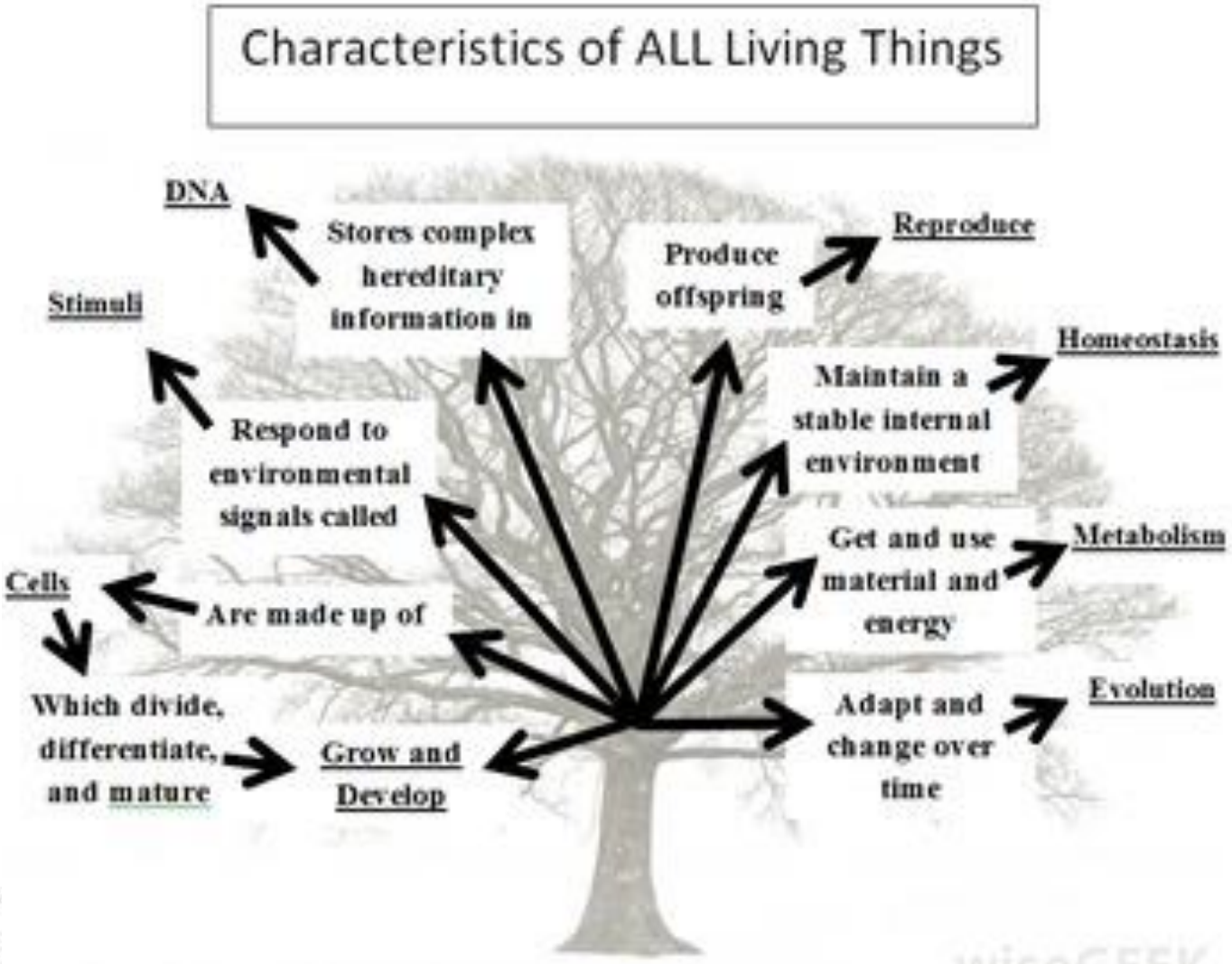
Organisation at scales



Organism the 1st level

Any unicellular or multicellular form exhibiting all of the characteristics of life





Individuals

- Trees can be found in many places, including cities, forests, parks, and gardens.
  - Urban areas
  - Street trees: Trees that line streets in cities
  - Parks: Trees in parks and other public spaces
  - Gardens: Trees in community, domestic, and school gardens
  - Canals and rivers: Trees that grow along canals and rivers
- Forests
  - Forest estates – wood pasture former hunting estates
  - Within forest plantations: where trees grow for multipurpose outcomes
  - Woodlands: that are connected to each other through a network that allows them to share nutrients and water, whether native semi-natural or novel urban ecosystems
- Other places
  - Hedgerows: Trees that grow in hedgerows
  - Amenity areas: Trees that have been predominantly planted and grow in amenity areas

Trees as a population

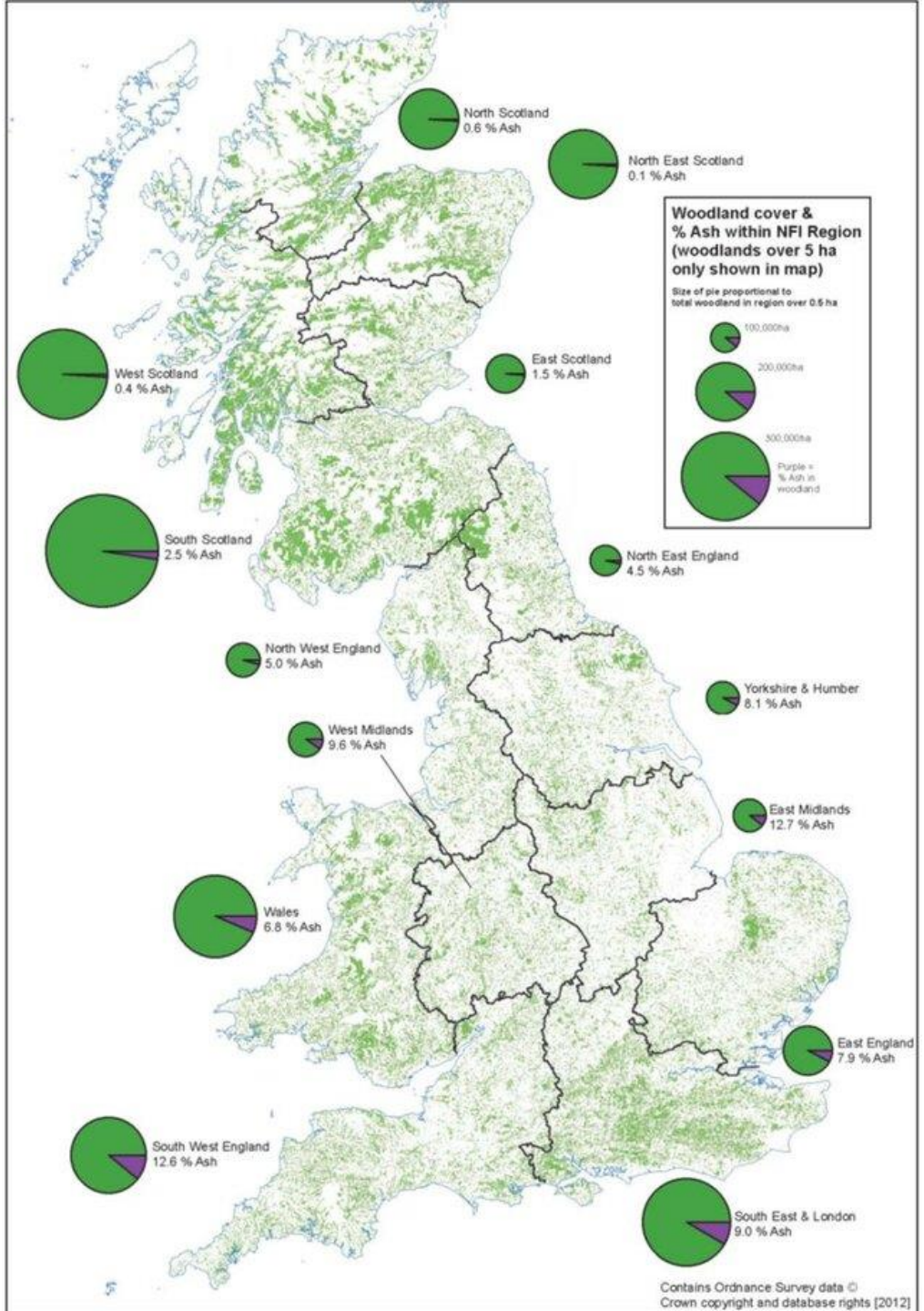
- A group of organisms of one species living in the same place at the same time that interbreed
- Produce fertile offspring
- Compete with each other for resources

Size of pie proportional to total woodland in region:

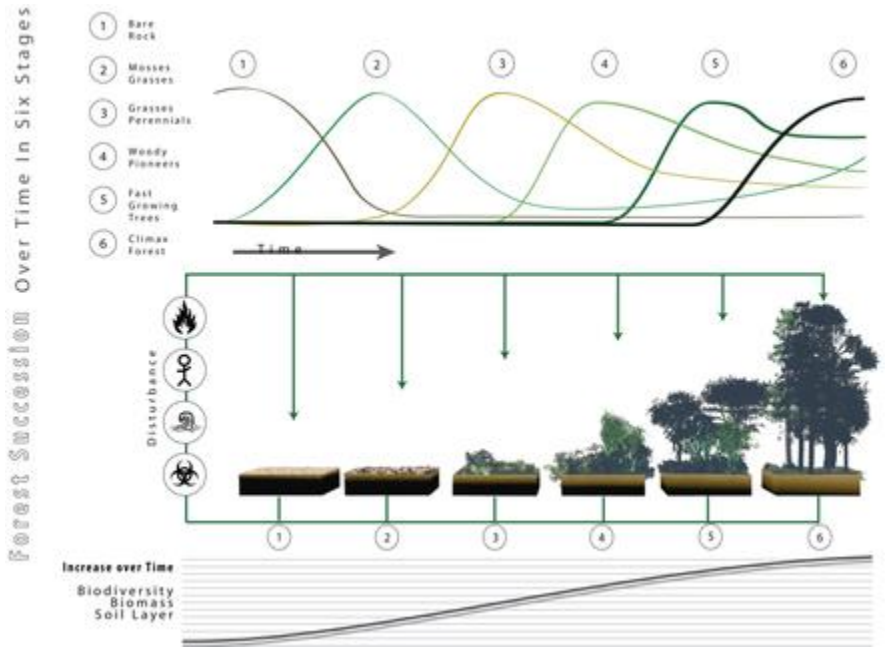
- smallest represent forest area up to 100 000 ha,
- medium up to 200 000 ha,
- large up to 300 000 ha.

Proportion of ash in each of the areas shown in violet

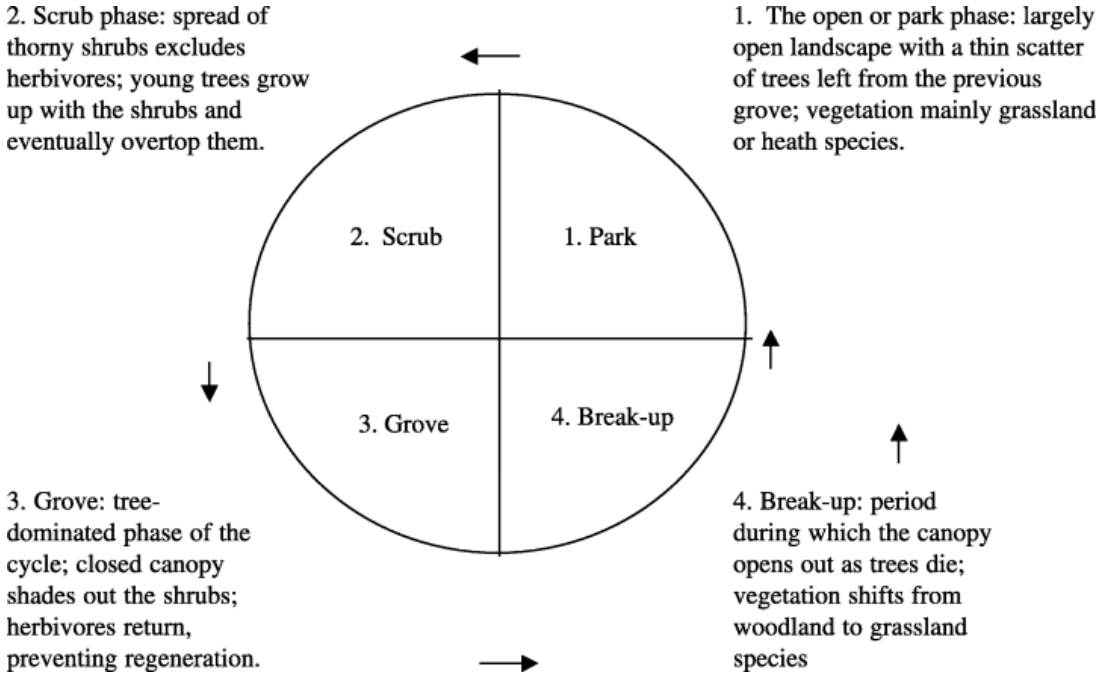
https://livingashproject.org.uk/wp-content/uploads/2020/08/Clark-and-Webber-2017-The-ash-resource-and-the-response-to-ash-dieback-in-Great-Britain.pdf



Communities



Frederic Clements: linear succession



Vera 2002 The dynamic europeaan forest
https://www.tandfonline.com/doi/epdf/10.1080/03071375.2002.9747335?needAccess=true

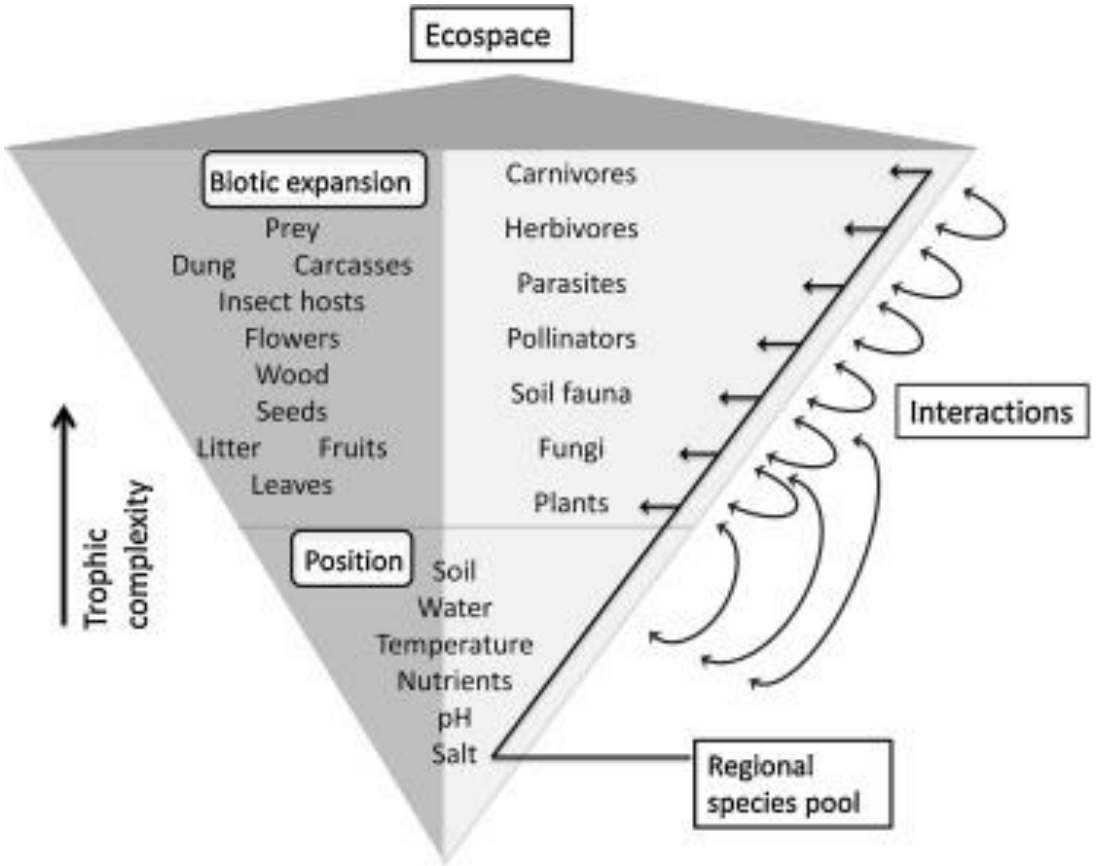
Habitat: a place where an organism makes its home.

- habitat refers to the array of resources, physical and living factors that are present in an area, such as to support the survival and reproduction of a particular species.
- Found across the UK in a wide range of habitats - woodland, f
  heathland, moorland

Insects form the bulk ~ 80 %

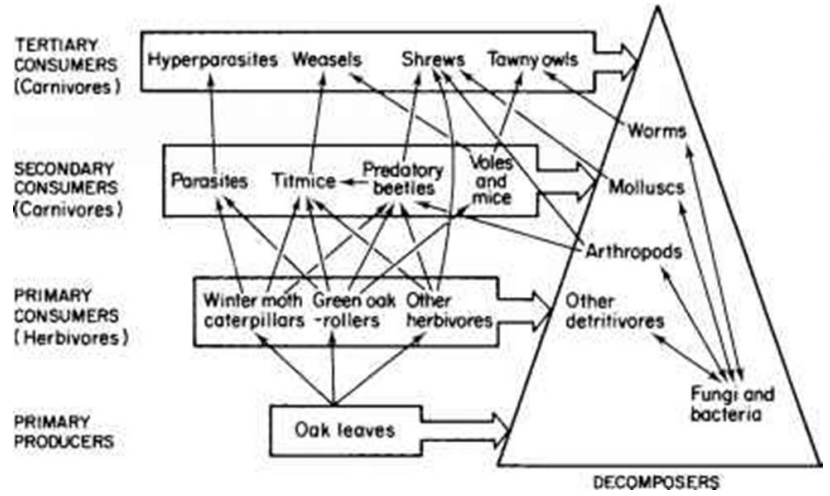
Wren: 11 million breeding pairs.

Ecospace – a more unifying and dynamic term



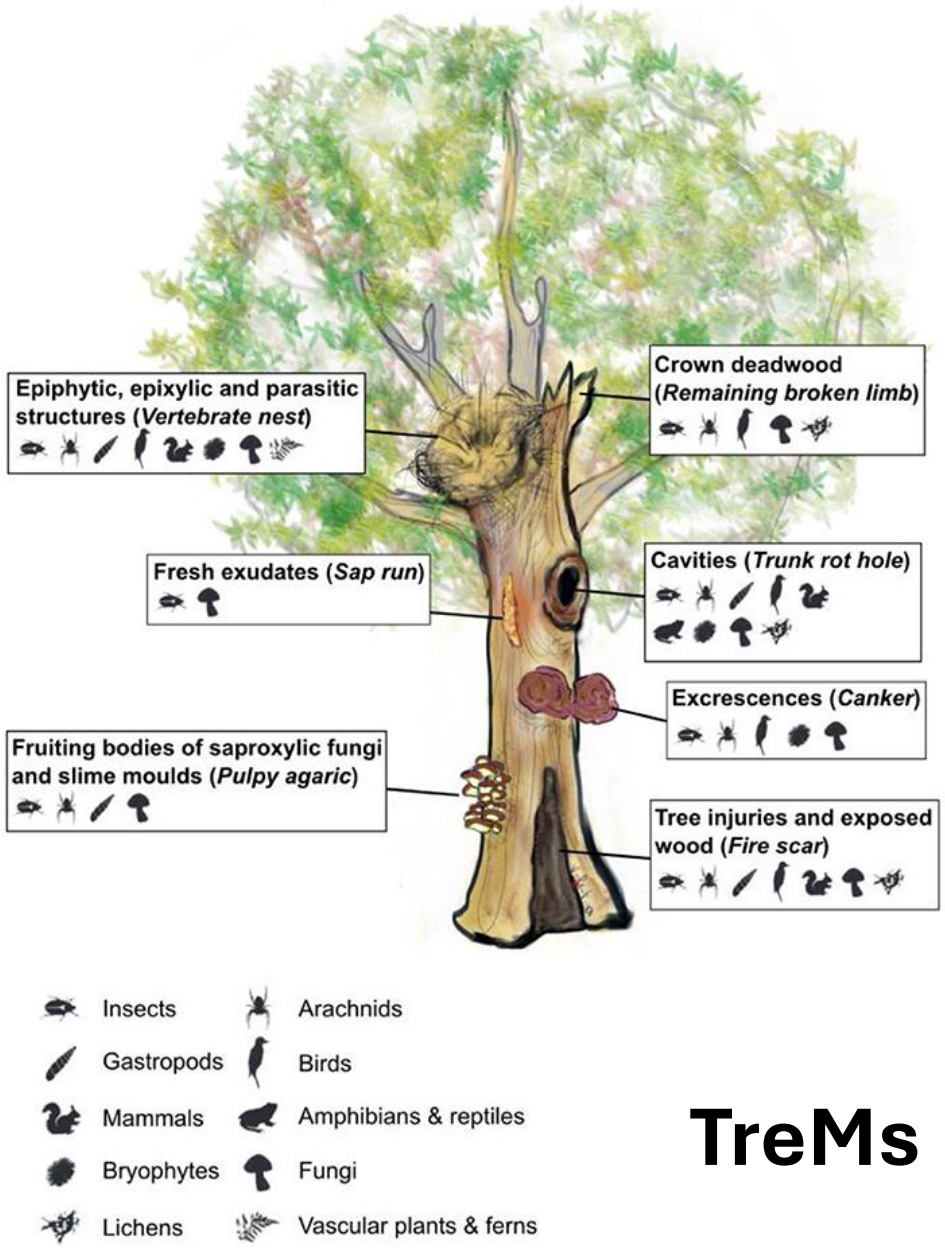
Encompasses:

- abiotic position,
- biotic expansion and
- temporal continuity,



Tree related micro habitats

1. **Cavities** are basically holes or shelters formed by cavity builders decay processes, morphological particularities on the trunk or collar (e.g. dendrotelms in forks or root-buttress shelters).
2. **Injuries expose sapwood** and sometimes also **heartwood** and create access for colonizing taxa.
3. **Crown deadwood** consists of dead branches in general occurring at the top of the tree; xero-thermophilous
4. **Excrescences** are mainly caused by reactive growth to an increase in light availability or to a parasitic or microbial intrusion (e.g. **canker, burr**).
5. **Fungal fruiting bodies and slime moulds** classified as perennial or ephemeral (lasting less than a year) structures.
6. **Epiphytic and epixylic structures**
7. **Exudates** are sap runs / heavy resinosis / excretions (pH)



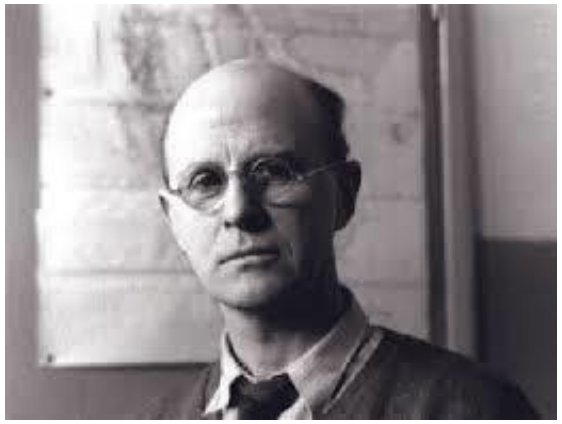
TreMs

Larrieu, L., Paillet, Y., Winter, S., Bütler, R., Kraus, D., Krumm, F., ... & Vandekerkhove, K. (2018). Tree related microhabitats in temperate and Mediterranean European forests: A hierarchical typology for inventory standardization. Ecological Indicators, 84, 194-207.

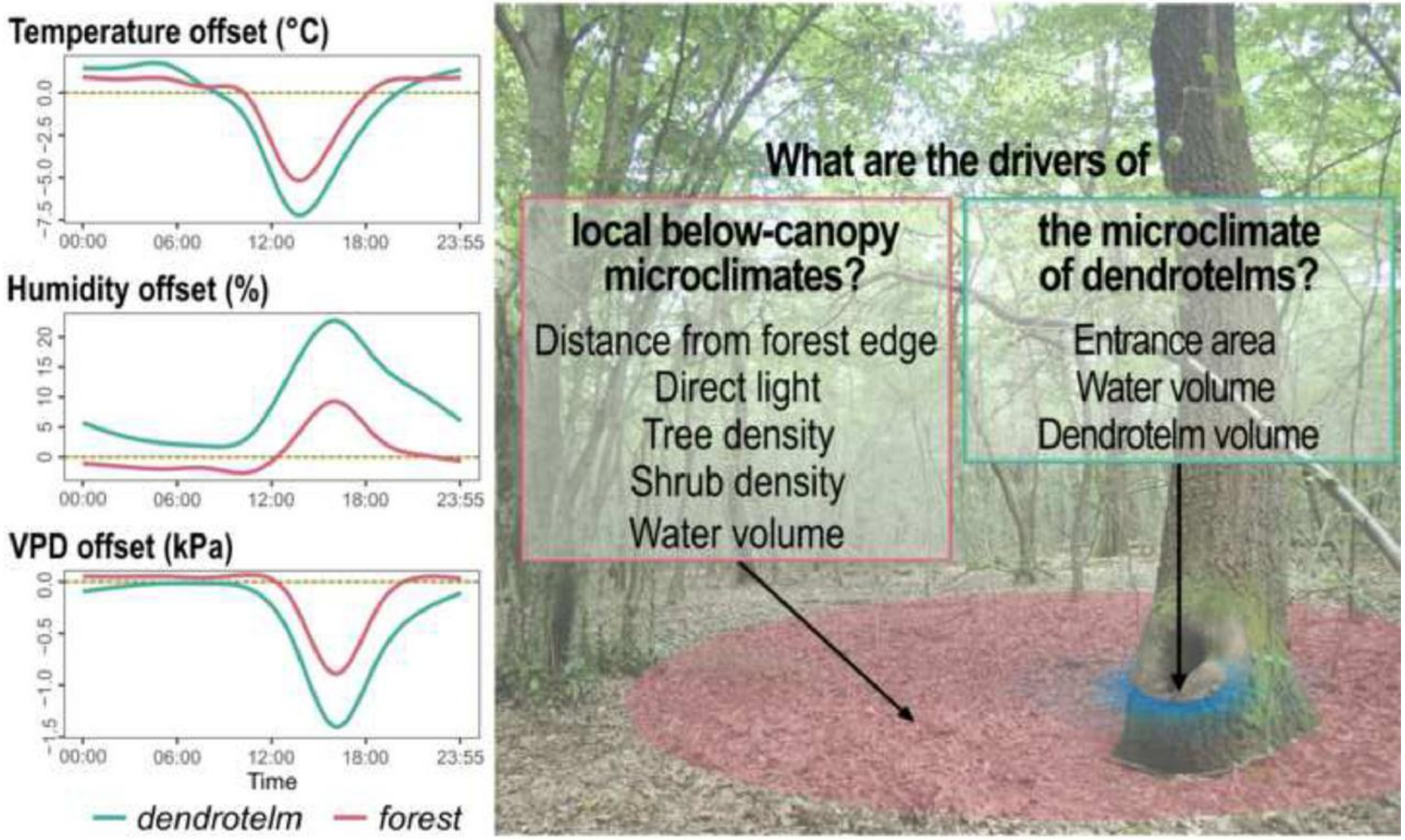
Concept of a niche: the how

An **ecological niche** is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' **niche** includes all of its interactions with the biotic and abiotic factors of its environment.

Niche: 1927 Charles S. Elton



Dendrotelms can create even cooler and more humid microclimates than closed forests

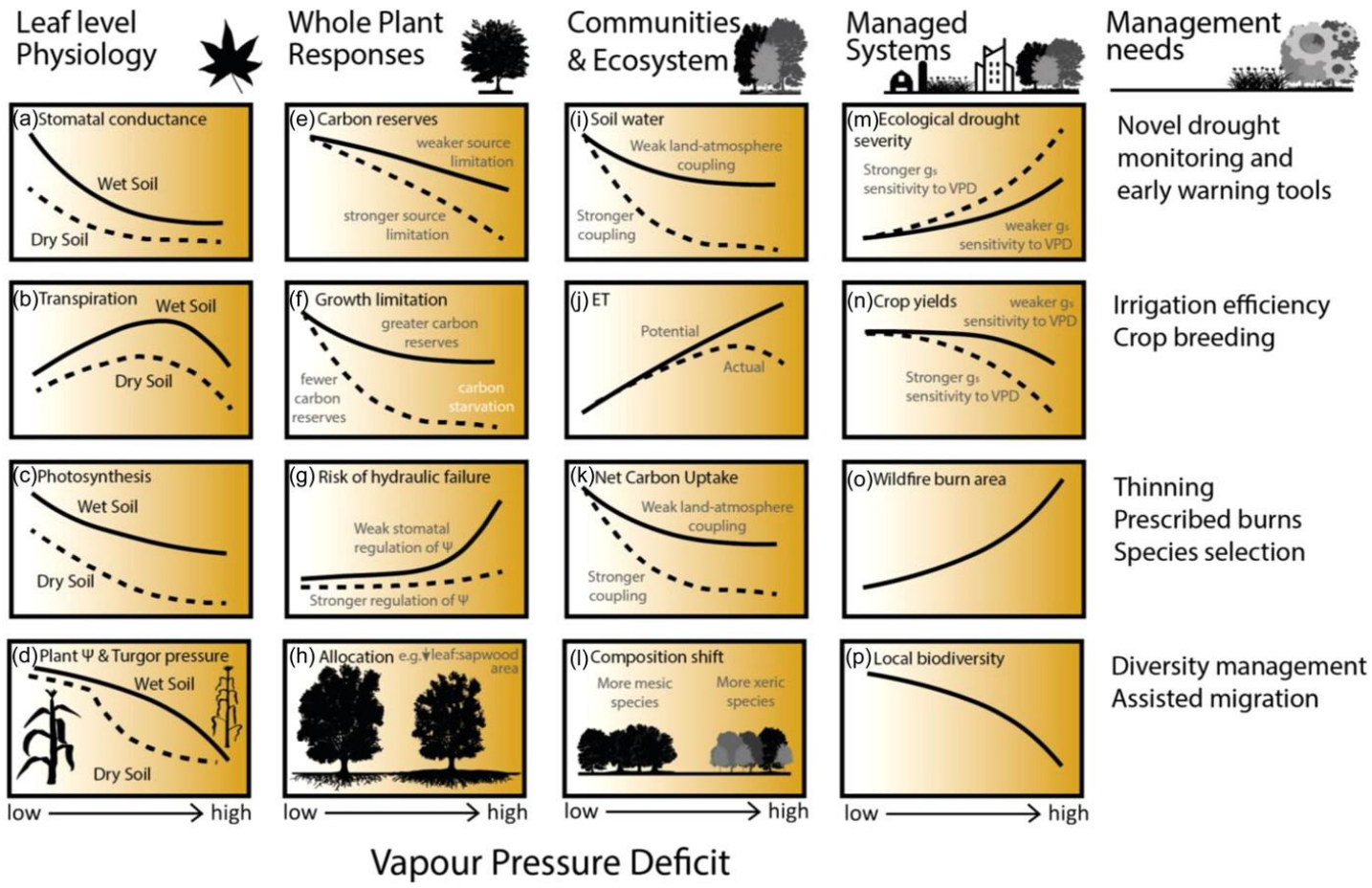


The role of dendrotelms as microclimatic refugia might increase under climate change

Kovacs et. al. 2024Small oases below the canopy: The cooling effects of water-filled tree holes on the local microclimate in oak-dominated stands https://doi.org/10.1016/j.agrformet.2024.110058

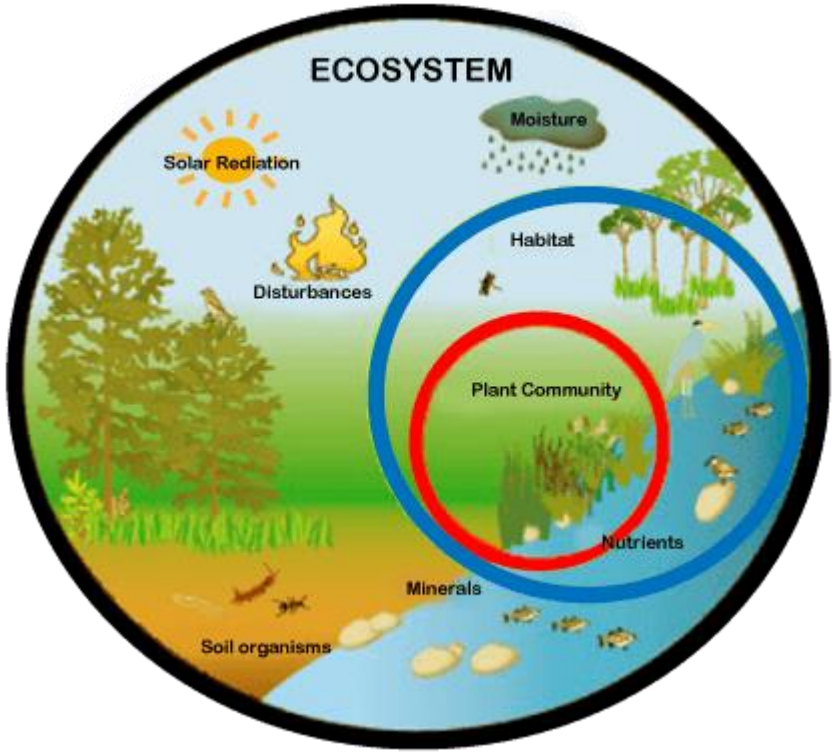
Vapour pressure deficit

VPD represents the desiccating strength of the atmosphere, rising VPD promotes a cascade of responses within plants and ecosystems



https://onlinelibrary.wiley.com/doi/10.1111/pce.14846

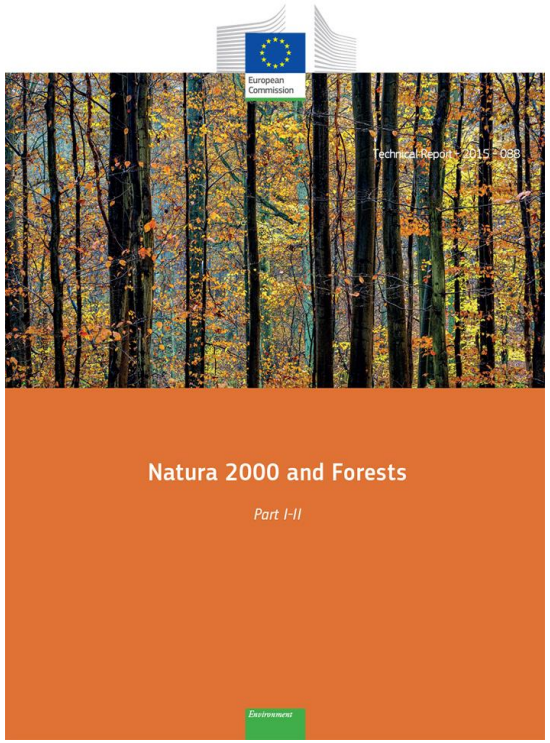
Ecosystem

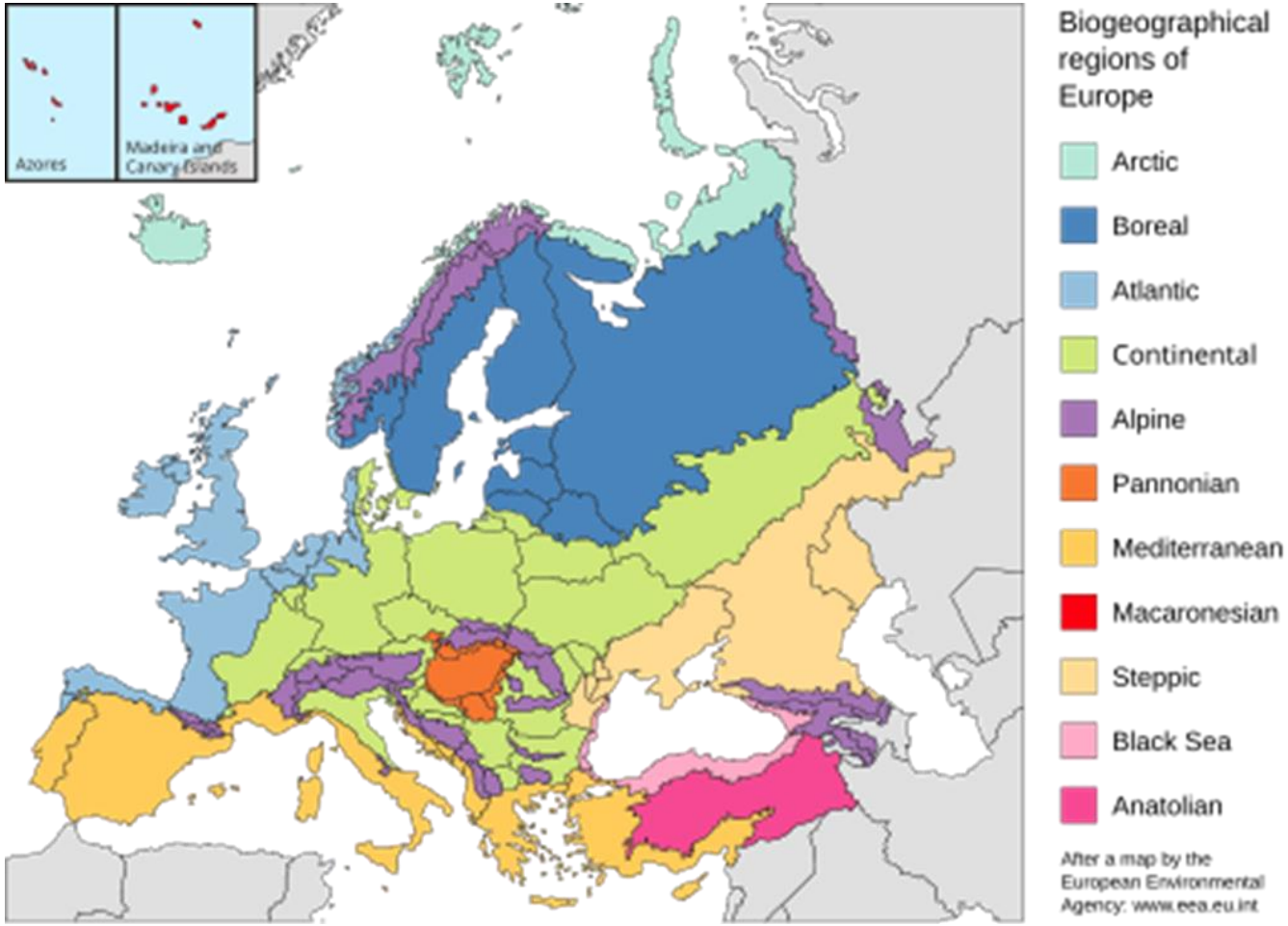


- Ecosystem “geobiocenosis” – a complex of a large number of communities in one climate region.
- a fundamental functional unit in ecology in which the abiotic and biotic environment are functionally stable at a certain trophic level of matter circulation

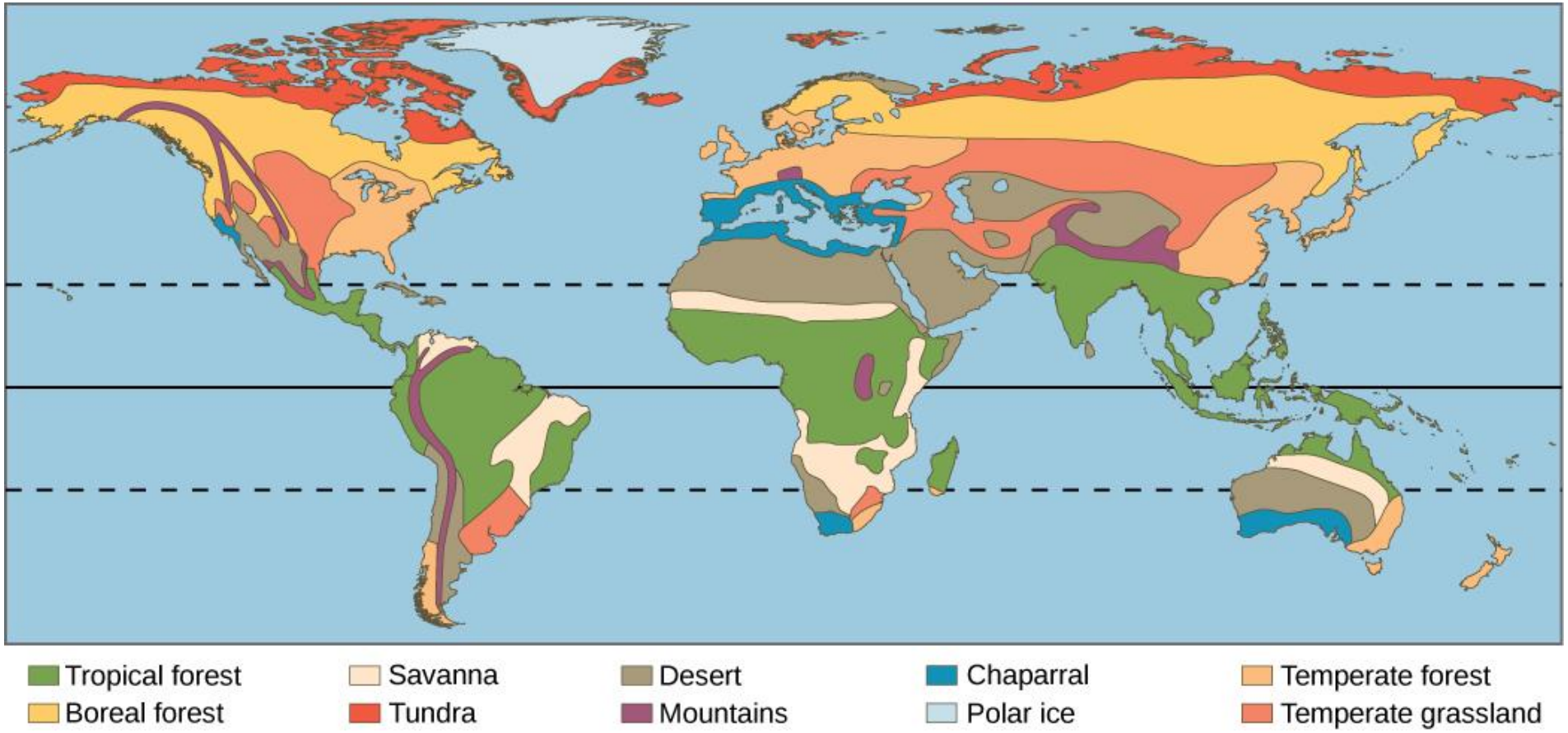
Bioregions - geographical area defined not by political boundaries but by ecological systems.

- Atlantic forest
- Boreal
- Etc.



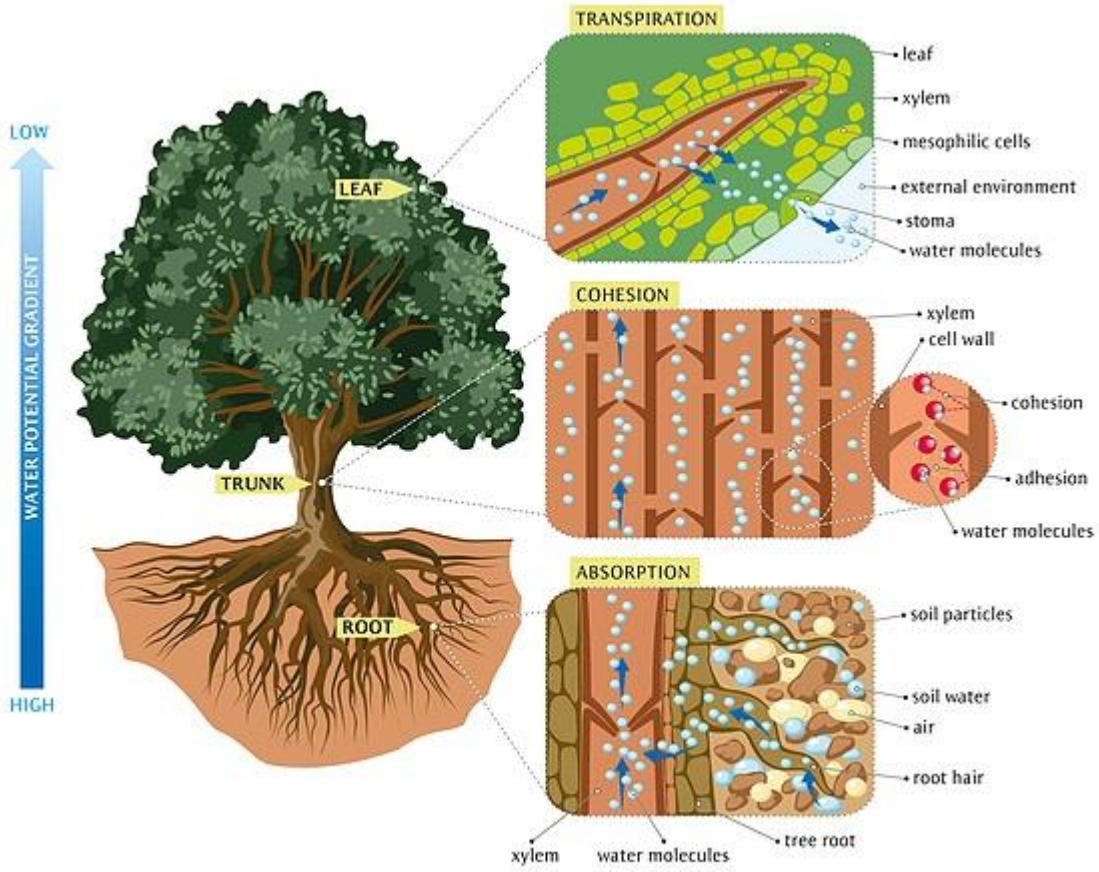


Biomes – largest geographic biotic unit (climate)



We are taught to ‘understand’ the tree as a living system

- Food manufacturing (photosynthesis)
- Storage (parenchyma in the meristems, medullary rays & leaf starch (apoplast))
- Cell division and elongation (growth)
- Respiration (production of energy)
- Defence system (CODIT…)
- Transpiration and gas exchange (waste disposal)
- Stability – root anchorage
- Support system – secondary thickening (lignification & bark formation)
- Reproduction – system end product

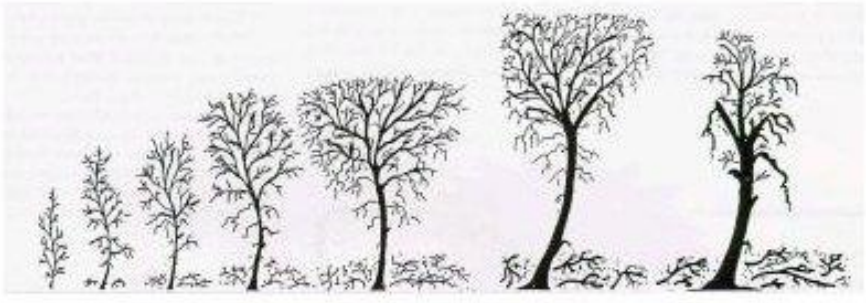


Alonzo, & Kindsvater 2008https://doi.org/10.1016/B978-008045405-4.00856-9

With a linear life history

Four phases in the life of a tree:

- Seedling
- Formative
- Mature
- Ageing (not Senescent)

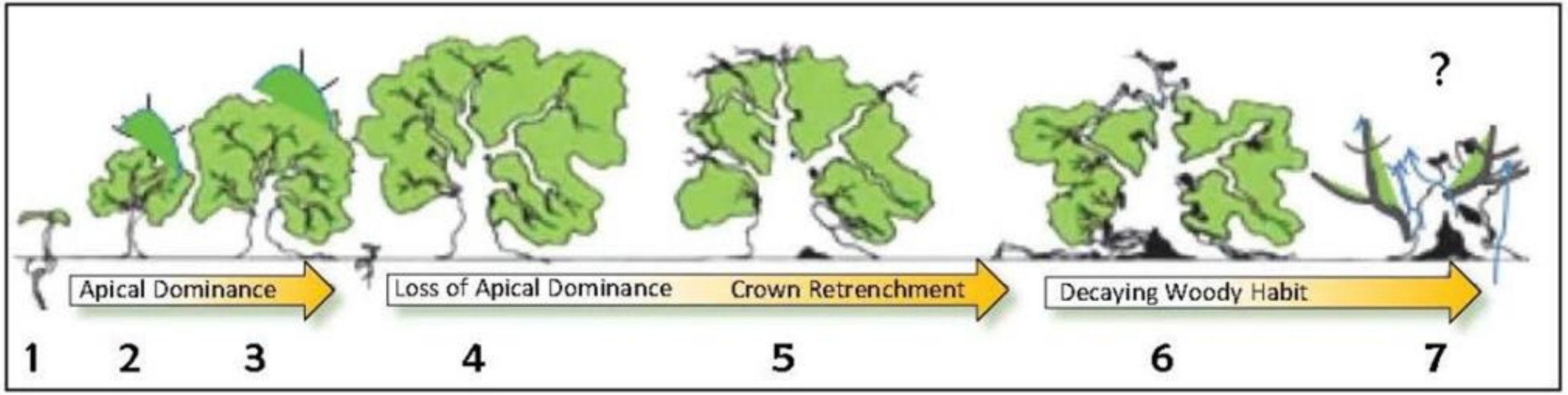


- Understanding ageing in trees should be understood in terms of the **cambial layer,** introducing the link between the influence of *external events* on physiological function, growth of anatomical structures and tree morphology.

However: 3 ways trees can age

- **Chronological ageing** is the duration since germination and may refer to the entire tree or a part of the tree. It is described solely in temporal terms.
- **Ontogenetical ageing** refers to the genetic potential of the individual tree. This is described in terms of development phases from germination to senescence. This view of ageing is influenced primarily by the activity of the meristematic tissue.
- **Physiological ageing** reflects primarily the senescence that is induced in the tree or part of the tree through abiotic and other stresses.

Generalised tree aging stages: after Fay 1987

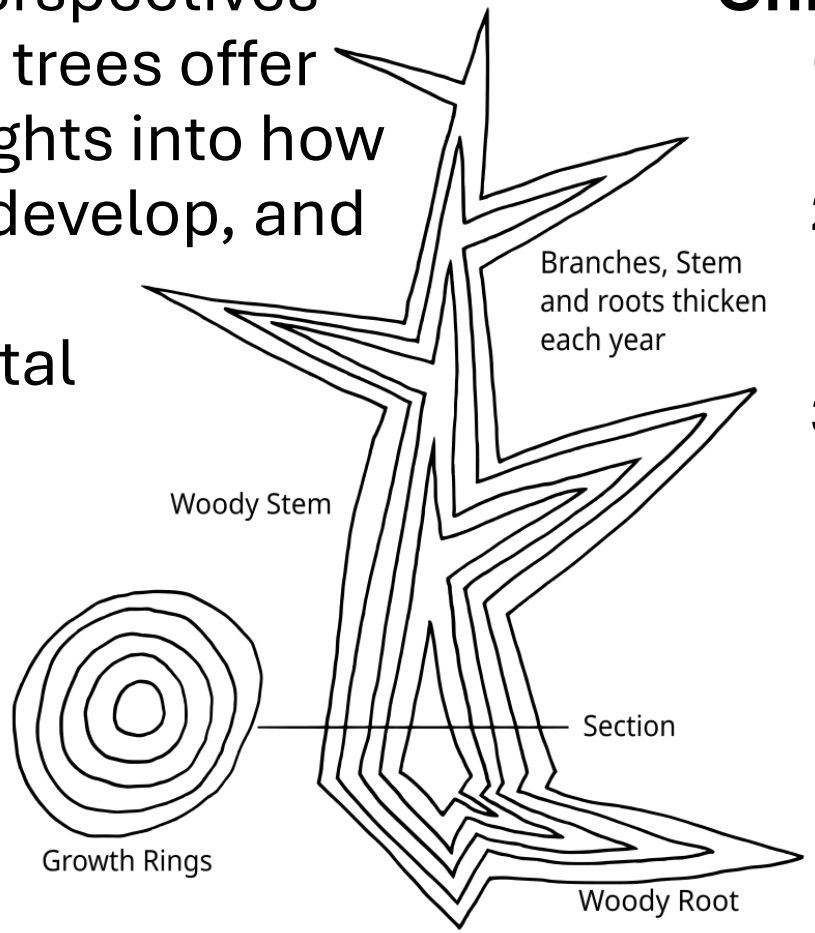


Traits vary over time - specifically, four separate processes generally co-occur during plant development: (1) plants get older (age);(2) plants get larger (size); (3) plants move through phase change (ontogeny); and (4) plants become more complex (architecture)

Ageing Process: from seedling to death in a standard tree in, Scottish Natural Heritage Research Report No. 789 – A review of the theory and practice of tree coring on live ancient and veteran trees https://www.nature.scot/sites/default/files/2018-09/Publication%202018%20-%20SNH%20Research%20Report%20789%20-%20A%20review%20of%20the%20theory%20and%20practice%20of%20tree%20coring%20on%20live%20ancient%20and%20veteran%20trees.pdf

Tree ageing

- The three perspectives on ageing in trees offer distinct insights into how trees grow, develop, and respond to environmental conditions:

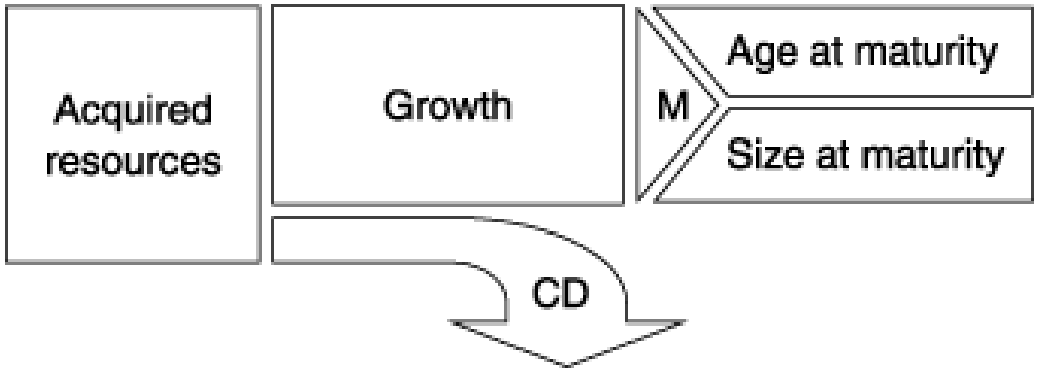


By Chiswick Chap - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=106194158

Chronological Ageing:

1. **Definition**: Measures the time elapsed since germination.
2. **Focus**: Entirely temporal and does not account for physiological or developmental changes.
3. **Significance**: Useful for determining the age of a tree for historical, ecological, or management purposes. It provides a straightforward measure but doesn't reflect the functional or developmental state of the tree.

Ontogenetical Ageing:

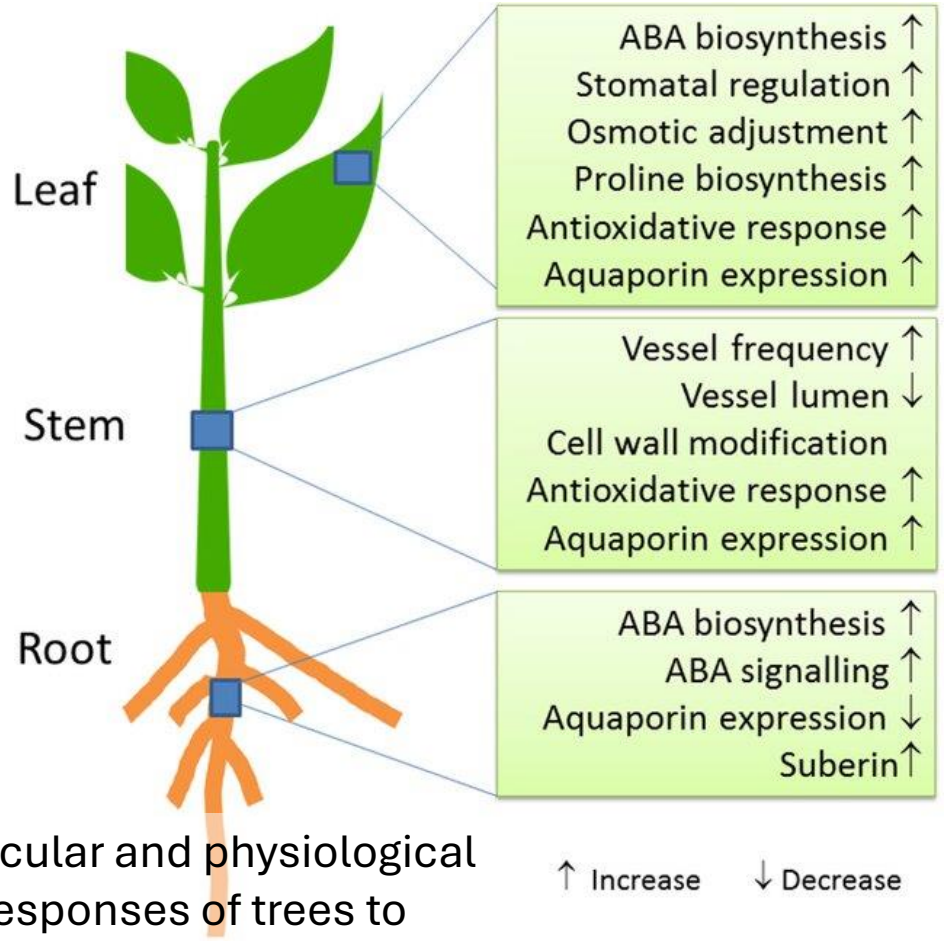


Simplified hierarchical representation of ontogeny, with age and size at maturity as phenotypic end-points (after Berner and Blanckenhorn 2007 https://doi.org/10.1111/j.1365-2435.2007.01253.x)

Key:
CD = competing demands
M = Maturation

1. **Definition**: Relates to the genetic potential and developmental phases of the tree, from germination to eventual senescence.
2. **Focus**: The lifecycle stages (e.g., phase change of juvenile, mature, senescent), driven by the activity of meristematic tissues (growth regions).
3. **Significance**: Highlights the biological potential and growth patterns of a tree. It's crucial for understanding growth dynamics, reproductive capacity, and how trees adapt their structure over time.

Physiological Ageing:



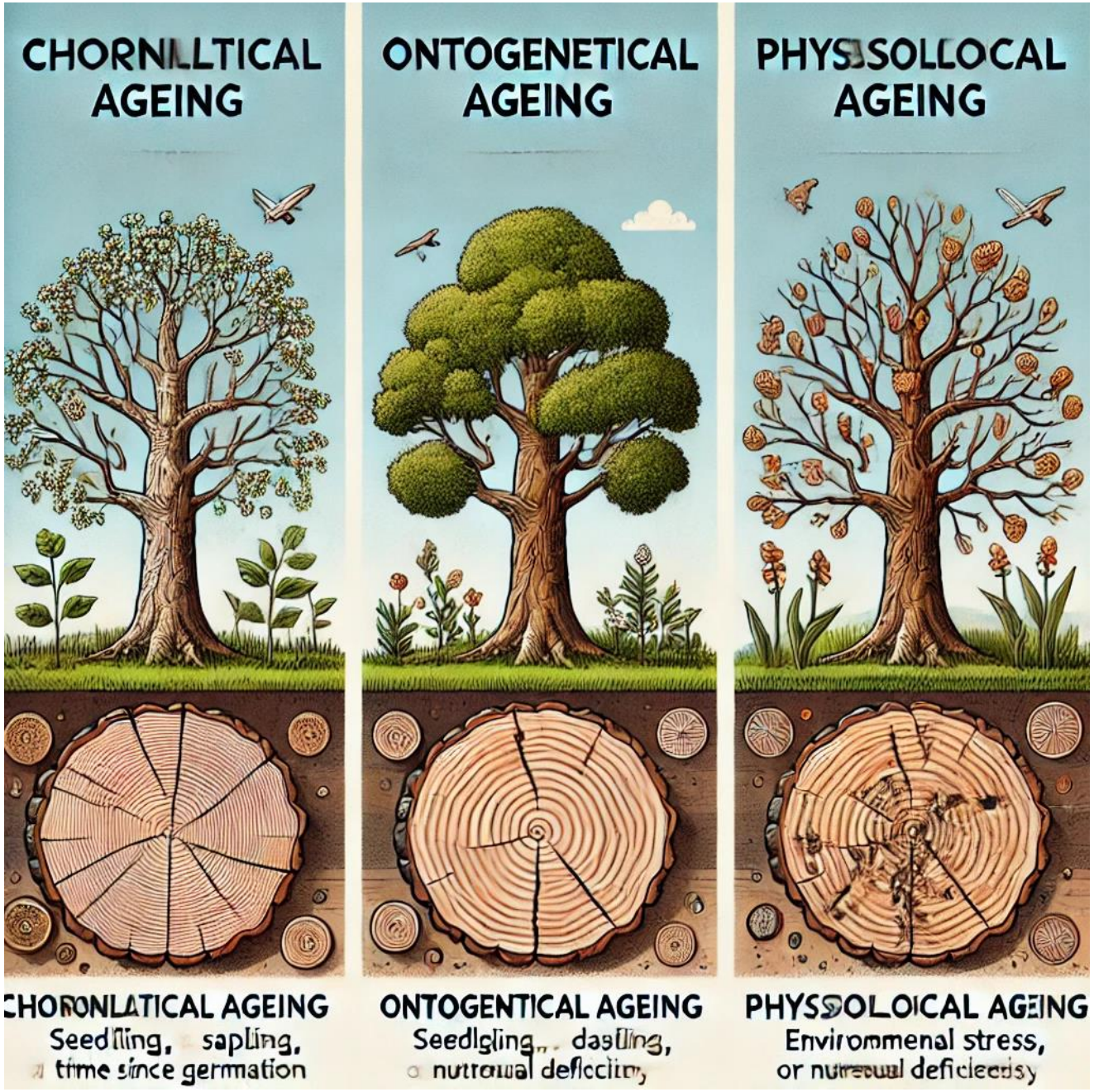
Molecular and physiological key responses of trees to drought stress.

1. **Definition**: Involves the ageing process influenced by environmental stresses, such as drought, disease, or nutrient deficiencies.
2. **Focus**: The functional decline or ageing at cellular and tissue levels due to external factors.
3. **Significance**: Offers insight into the health, vitality, and stress resilience of a tree. It's particularly important in forestry, conservation, and understanding the effects of climate change.

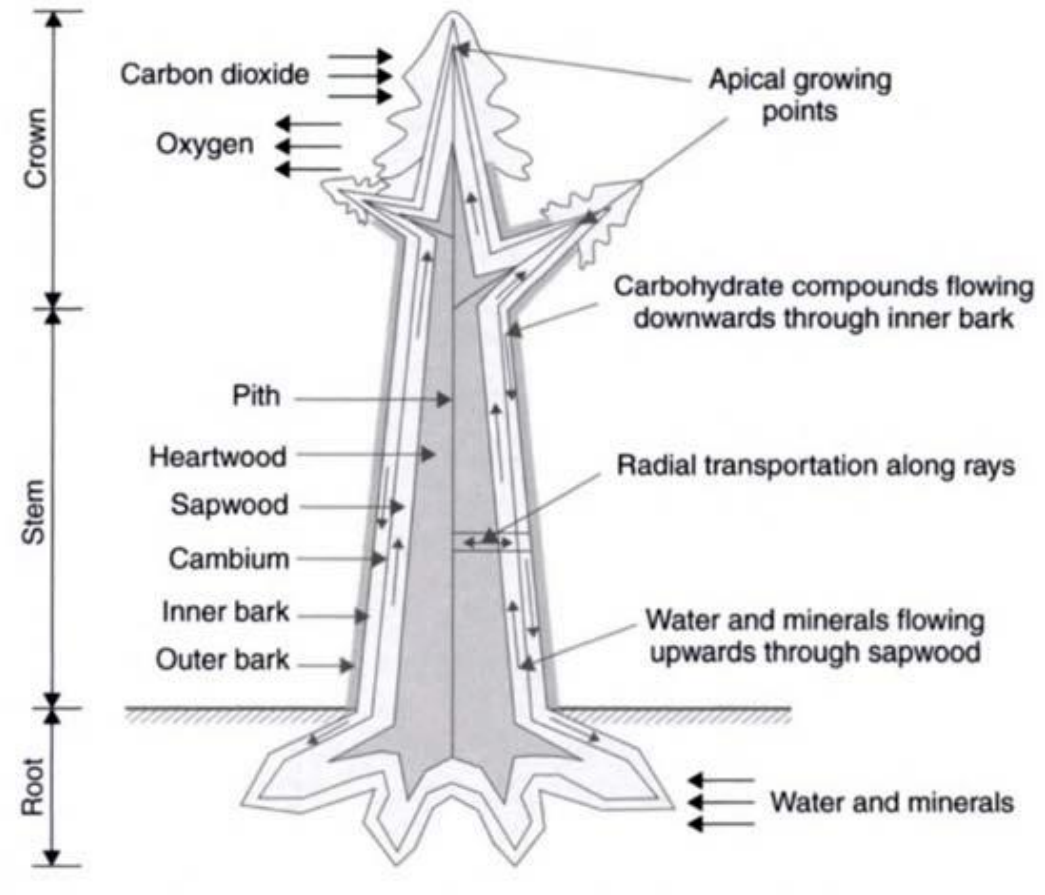
Note: A significant review suggests that tree mortality is mainly due to external influences, rather than to internal ageing. Brutovská et. al. 2013 https://doi.org/10.1016/j.arr.2013.07.001

Key take home:

By analysing these perspectives together, researchers and ecologists can gain a holistic understanding of tree ageing, which aids in conservation, urban forest management, and understanding ecosystem dynamics.



Tree form and function



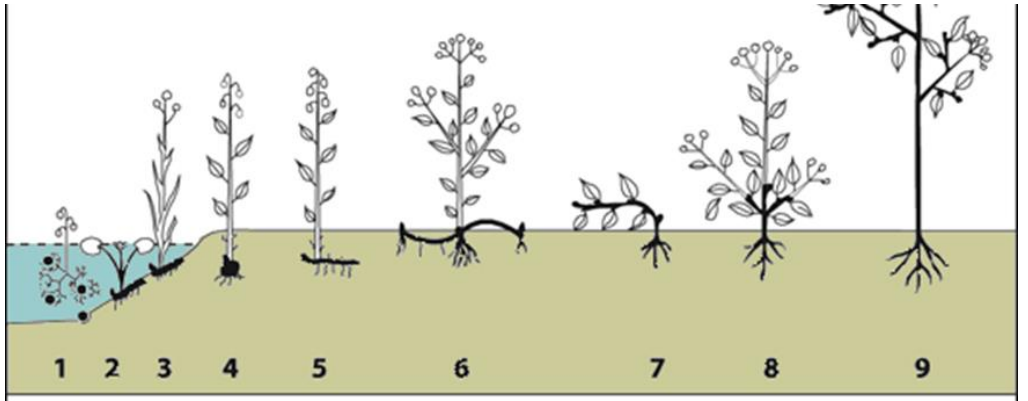


Diagram of the most important life forms based on the classification by Raunkiaer (1934)

1 + 2	Hydrophytes	(Hydr.)	water plants
3	Helophytes	(Helo.)	winter buds under water
			flowering plants above water
4 + 5	Crytophytes or geophytes	(Geof.)	winter buds below ground
6	Hemicryptophytes	(Hemi.)	winter buds above or just below ground
7 + 8	Chamaephytes	(Cham.)	winter buds up to 50 cm above ground
9	Phanerophytes	(Phan.)	winter buds at least 50 cm above ground (i.e. trees, shrubs and lianes)

Tree ecosystem:

Trees are ecosystems because they contain living and non-living parts that interact.

- The living parts include the tree's roots, trunk, branches, and leaves.
- Non-living parts include the physical environment, such as the soil and climate but also the dead wood (and extruded necromass).

Main parts of a tree and their function, after Teischinger, Alfred. (2016). OPPORTUNITIES AND LIMITS OF TIMBER IN CONSTRUCTION.

Liminal organisms (dead or / and alive)

- Change in environment leading to stress (reversible) or incrementally to strain (non-reversible).
  - Can be Edaphic/climatic/anthropogenic
- Sapwood damage or biotic colonisation
- The progressive thinning and attenuation of radial increments of new wood & bark around the core (as girth increases)
- Occlusion (regenerative growth) or
- Development of xylem dysfunction, oxidation & decay columns
- Dendrotelms are one of many types of tree-related microhabitats (TreMs).

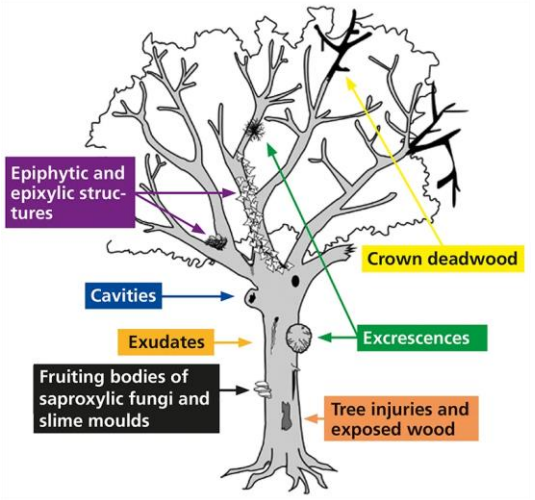
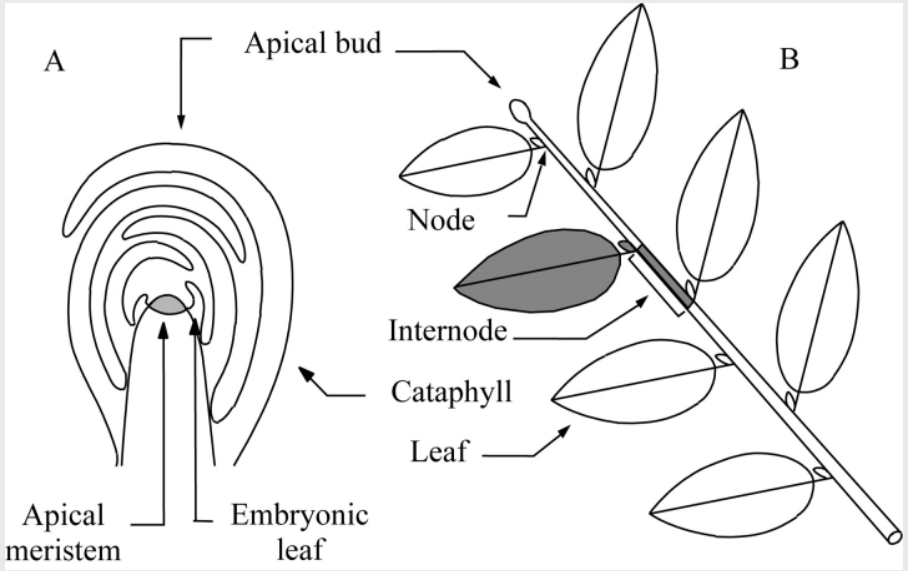


Photo: Rita Bütler (WSL)

Field guide to TreMs https://www.waldwissen.net/en/forest-ecology/nature-conservation/field-guide-to-tree-related-microhabitats

Gleditsia triacanthos ‘inermis’

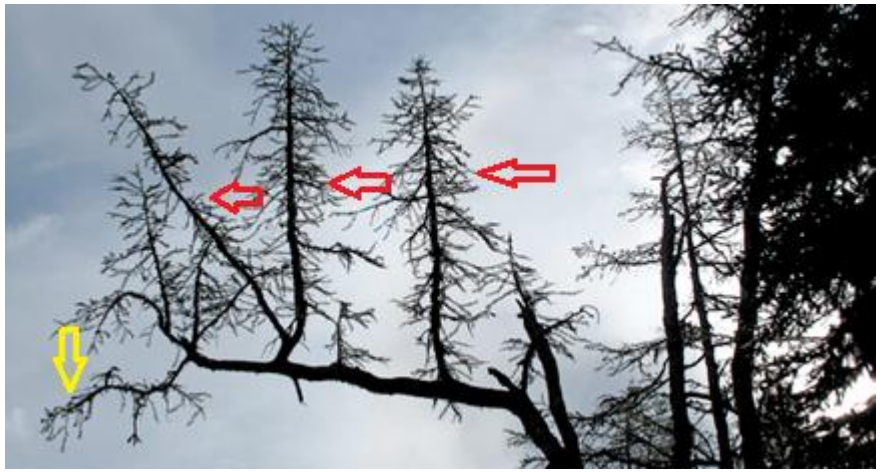
Ontogenetical rejuvenation



https://cdn.ymaws.com/www.asca-consultants.org/resource/resmgr/consultant_repurposing/aging_and_rejuvenation_in_tr.pdf

Regenerative modular organisms: sweet chestnut with one strip of functional stem tissue

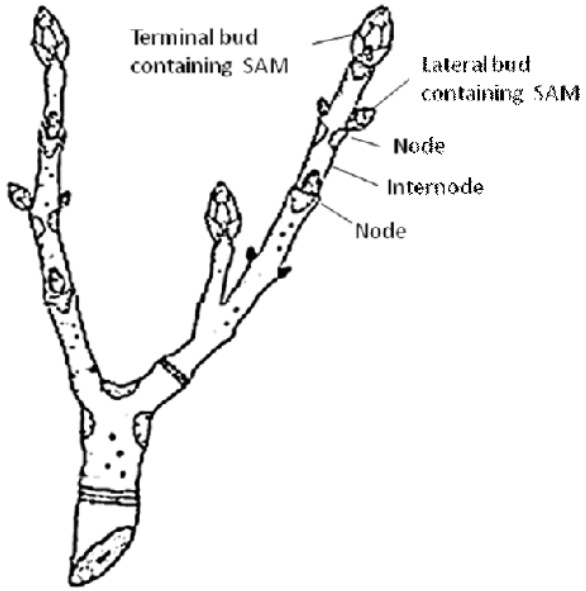
Phoenix trees and reiterative growth



https://greenlab.cirad.fr/GLUVED/html/P1_Prelim/Bota/Bota_unit_006.html

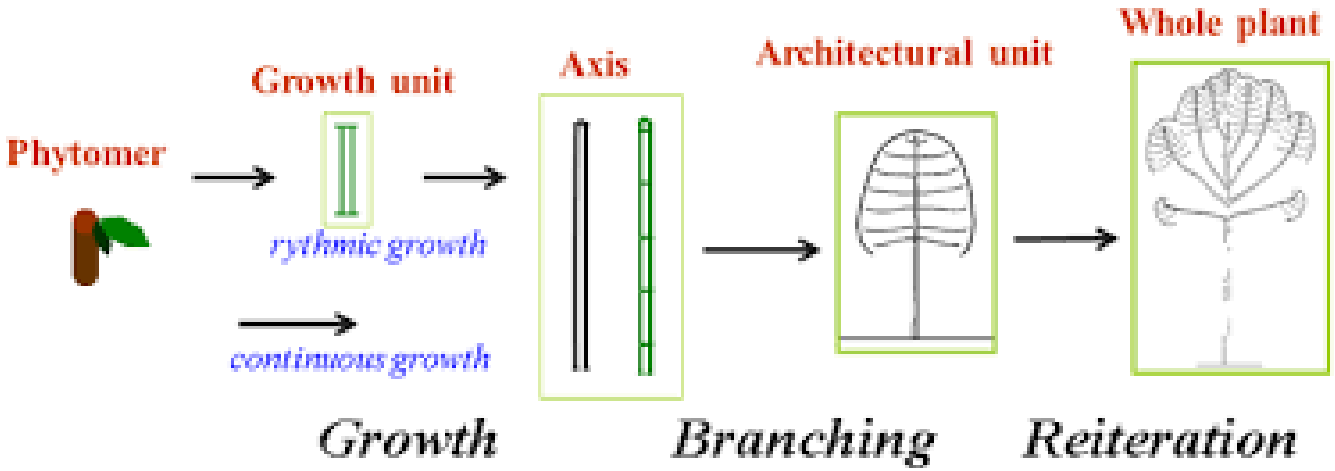
Tree mortality is mainly due to external influences, rather than to internal ageing…

- Longevity of trees can depend on environmental conditions.
- Single tree can behave as a population of modules, which can age individually.



Factors that contribute to physiological aging

- Environmental stress: Trees can experience stress from water availability, rot fungi, insects, and disease.
- Damage: Trees can be damaged by wind, fire, ice, or snow.



Factors that affect how trees age

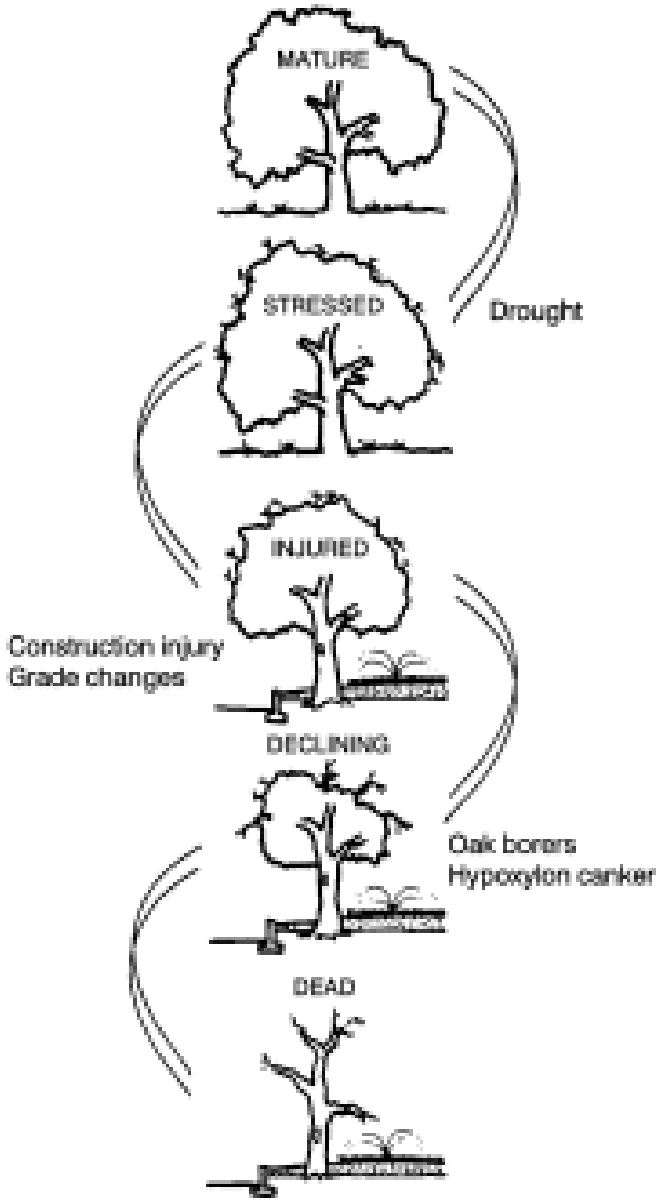
- Genetics: The timing of developmental transitions is regulated genetically.
- Life history: Different species have different life histories that affect how they age.

Brukhin, Vladimir & Morozova, N.. (2011). Plant Growth and Development - Basic Knowledge and Current Views. Mathematical Modelling of Natural Phenomena. 6. 1 - 53. 10.1051/mmnp/20116201 .

Mortality spirals & energy budgets

Biology: How Do Trees Die?

- Mortality and Longevity: two sides of a coin.
- Most trees die of competition, fire, insect attack, human action, or fungal attack.
- Causes may interact; may be synergistic.



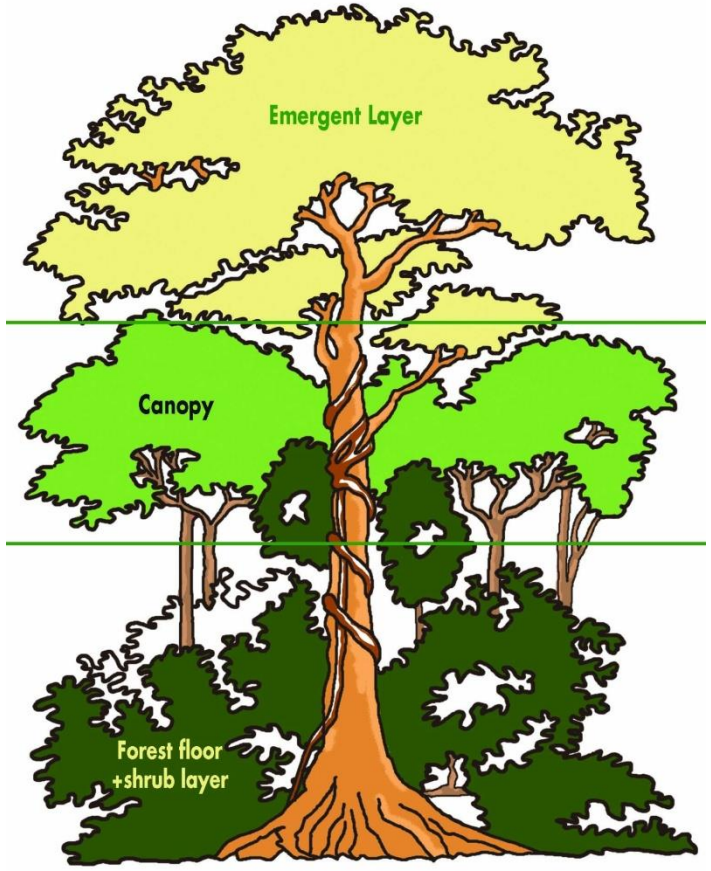
Avoidable or a least can be delayed – regenerative organisms

Where do trees grow

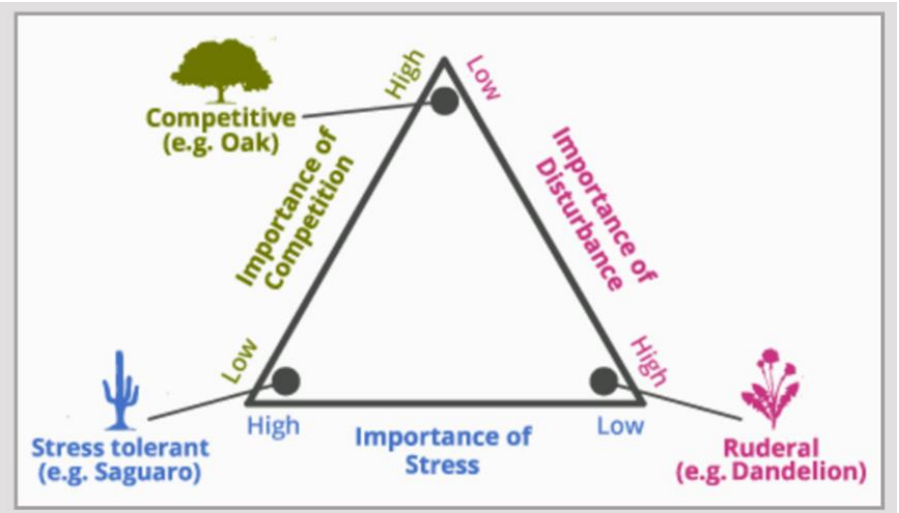
- Social constructs
  - Woodland, copse, grove, Forest, forest, plantations,
  - Fields, hedges, boulevards, avenues, gardens, parklands, streets
- Matrix habitats
  - Grassland, heathland, riparian edge, moorland, mountain, dune slack, bog,
- Biomes
  - Tundra, Rain Forest, Savanna, Boreal forest, Temperate forest, Temperate grassland, Mountains, Desert…

Tree growth not as individuals but in communities as part of a matrix of habitats

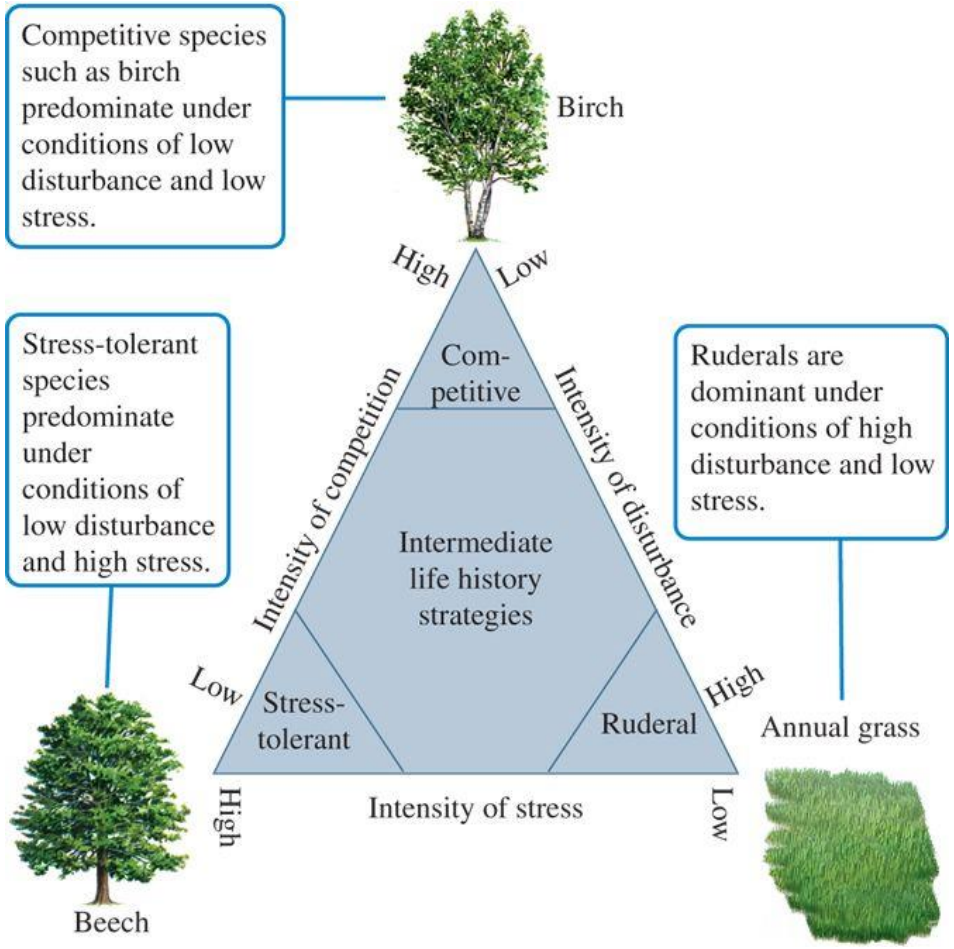
- During the early stage of a trees life it colonises the space available to it as determined by the environmental conditions and the trees inherent physiological conditions and growth potential.



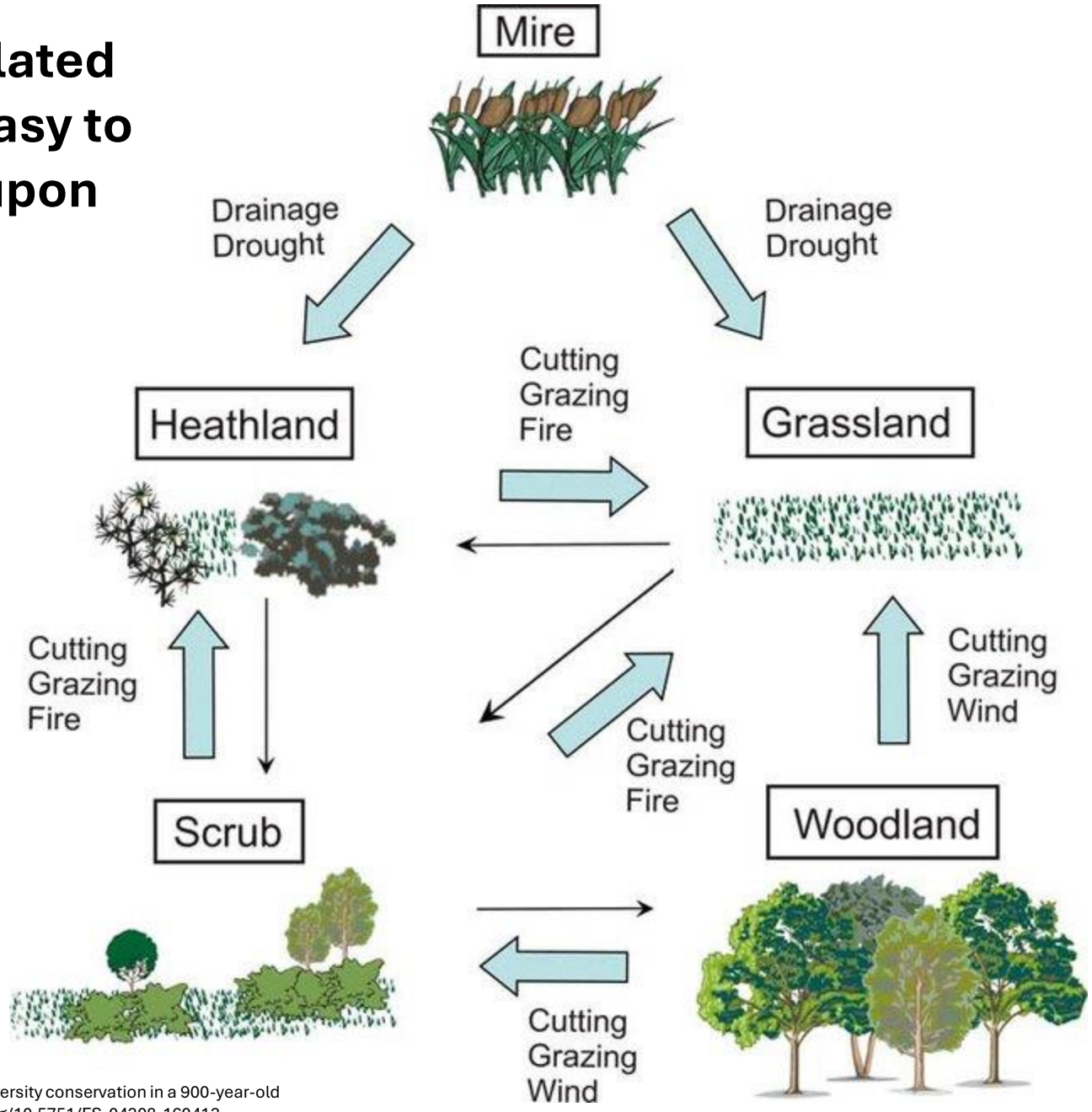
Life history strategies



- Competitive (top corner)
- Stress-tolerant (lower left corner)
- Ruderal (lower right corner)
- Mixed (center of triangle)



Dynamic, interrelated and not always easy to define depends upon externalities



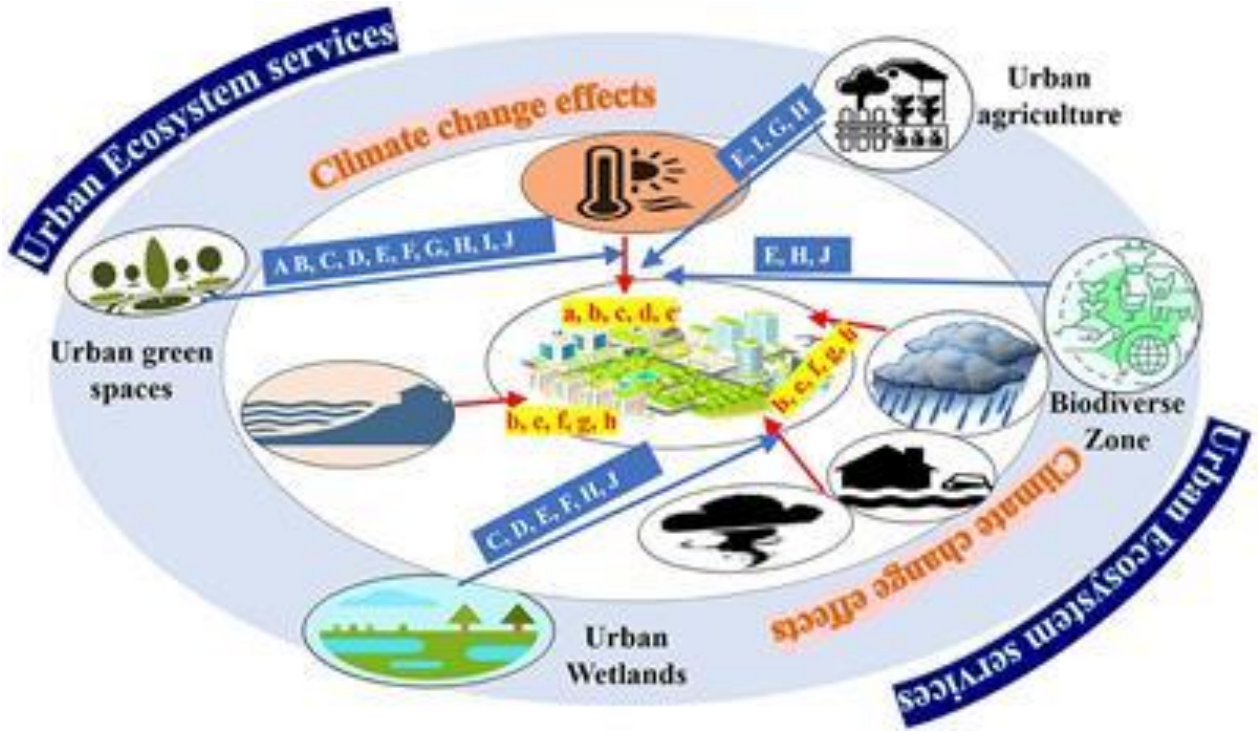
Newton, A.C. (2011). Social-ecological resilience and biodiversity conservation in a 900-year-old protected area. Ecology and Society, 16, 13. http://dx.doi.org/10.5751/ES-04308-160413

Fastest growing habitat in world

Urban trees?

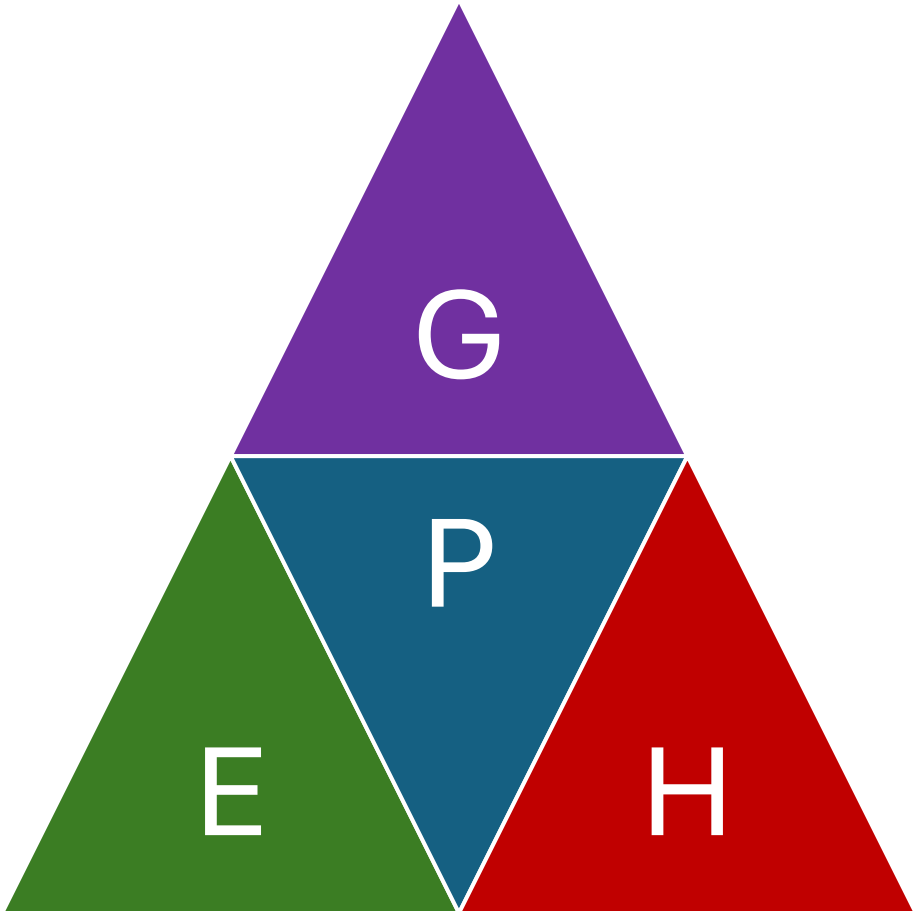
Oldfield, E. E., Warren, R. J., Felson, A. J., and Bradford, M. A. (2013). Challenges and future directions in urban afforestation. J. Appl. Ecol. 50

https://www.barbourproductsearch.info/shouting-from-the-tree-tops-the-benefits-of-tree-news084637.html



Bhanu & Annesha 2023Urban ecosystem services and climate change: a dynamic interplay

Perceived vegetation



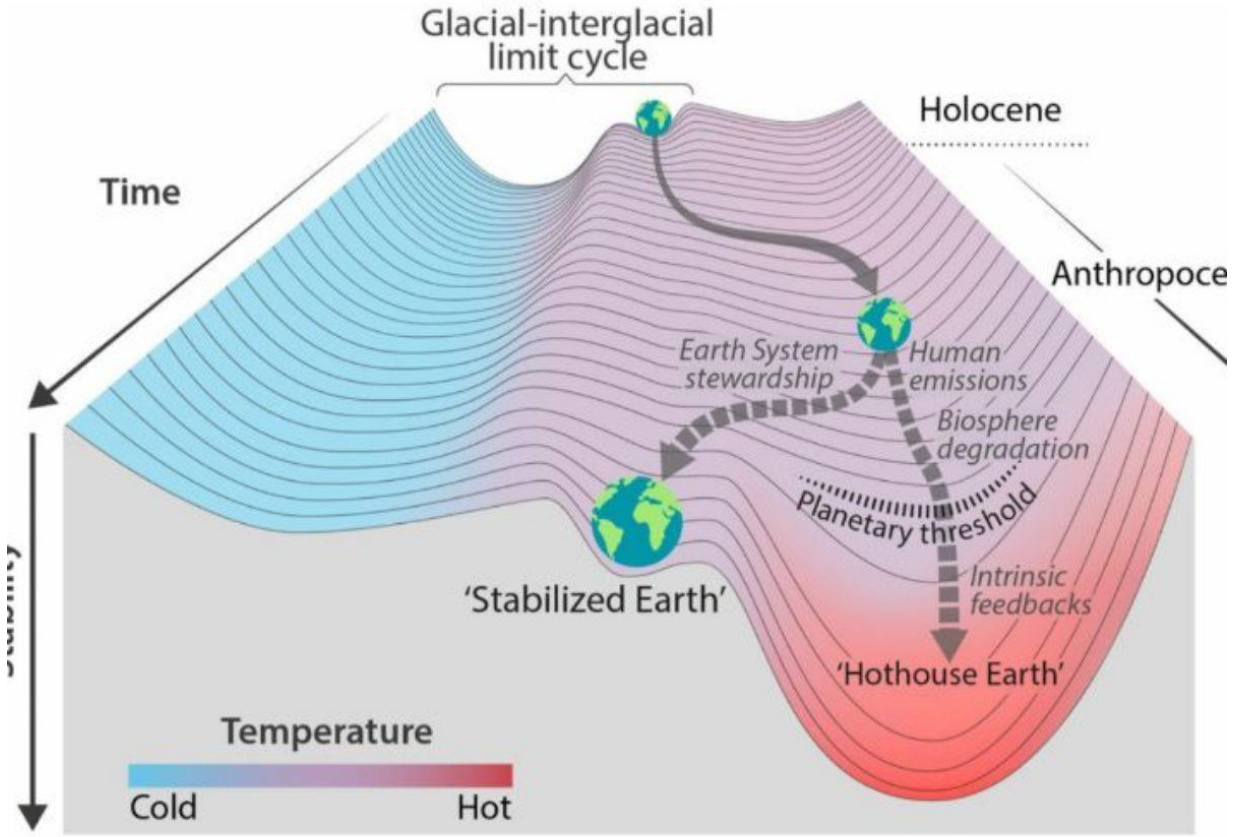
Perceived (target) vegetation

Genotype

Environment

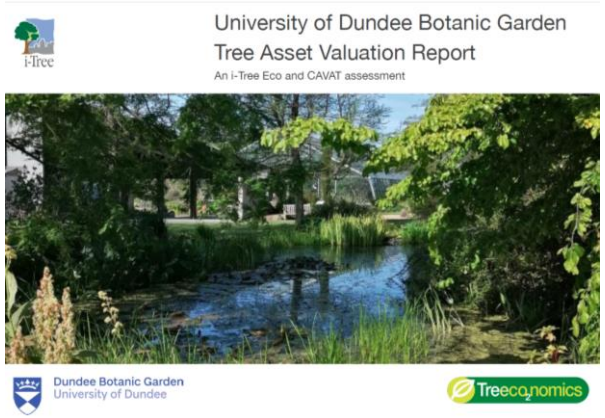
Human effort (resource inputs)

Tipping points: mitigation & adaptation



https://earth.org/data_visualization/tipping-points-in-the-earth-system/

University of Dundee



Headline Figure

Data processed using i-Tree Eco version 6.0.32

Structure and Composition	
Number of Trees	1,378
Number of Species	243
Most Common Tree Species	*Pinus sylvestris, Betula pendula, Eucalyptus gunni*
Replacement Cost (CTLA)	£1.48 million
Amenity Valuation (CAVAT)	£38.1 million

Combined Botanic Garden & Campus Ecosystem Services		
Annual Carbon Storage	633 tonnes	£624,000
Annual Carbon Sequestration	15.7 tonnes	£15,400
Annual Pollution Removal	60.3 kg	£4,400
Annual Avoided Runoff	1,600 m³	£2,600
Total Annual Benefits	**£22,400**	

Individual Level Ecosystem Services			
Annual Carbon Storage	Botanic Garden	498 tonnes	£491,000
	Campus	135 tonnes	£133,000
Annual Carbon Sequestration	Botanic Garden	11.8 tonnes	£11,600
	Campus	3.9 tonnes	£3,800
Annual Pollution Removal	Botanic Garden	45.6 kg	£3,300
	Campus	14.7 kg	£1,100
Annual Avoided Runoff	Botanic Garden	1,200 m³	£2,000
	Campus	400 m³	£600
Total Annual Benefits		**£22,400**	

Number of Trees: 1,378 records were used in this analysis. Exclusions detailed in Appendix II.

Replacement cost: Council of Tree and Landscape Appraisers Methodology from the Royal Institute of Chartered Surveyors. *Hollis, 2007

Amenity valuation (CAVAT): Capital Asset Valuation for Amenity Trees (CAVAT) is a method developed in the UK to provide a value for the public amenity trees provide. *Doick, 2018

Carbon storage and carbon sequestration values: These are calculated based on figures jointly published by the Department for Energy Security and Net Zero, and the Department for Business, Energy & Industrial Strategy, at a sum of £269 per metric tonne of CO_2e. *Gov.uk, 2012

Pollution removal: This value is calculated based on the UK social damage costs; £23,314 per tonne (nitrogen dioxide), £17,118 per tonne (sulphur dioxide), £172,816 per tonne (particulate matter less than 2.5 microns). *DEFRA, 2023

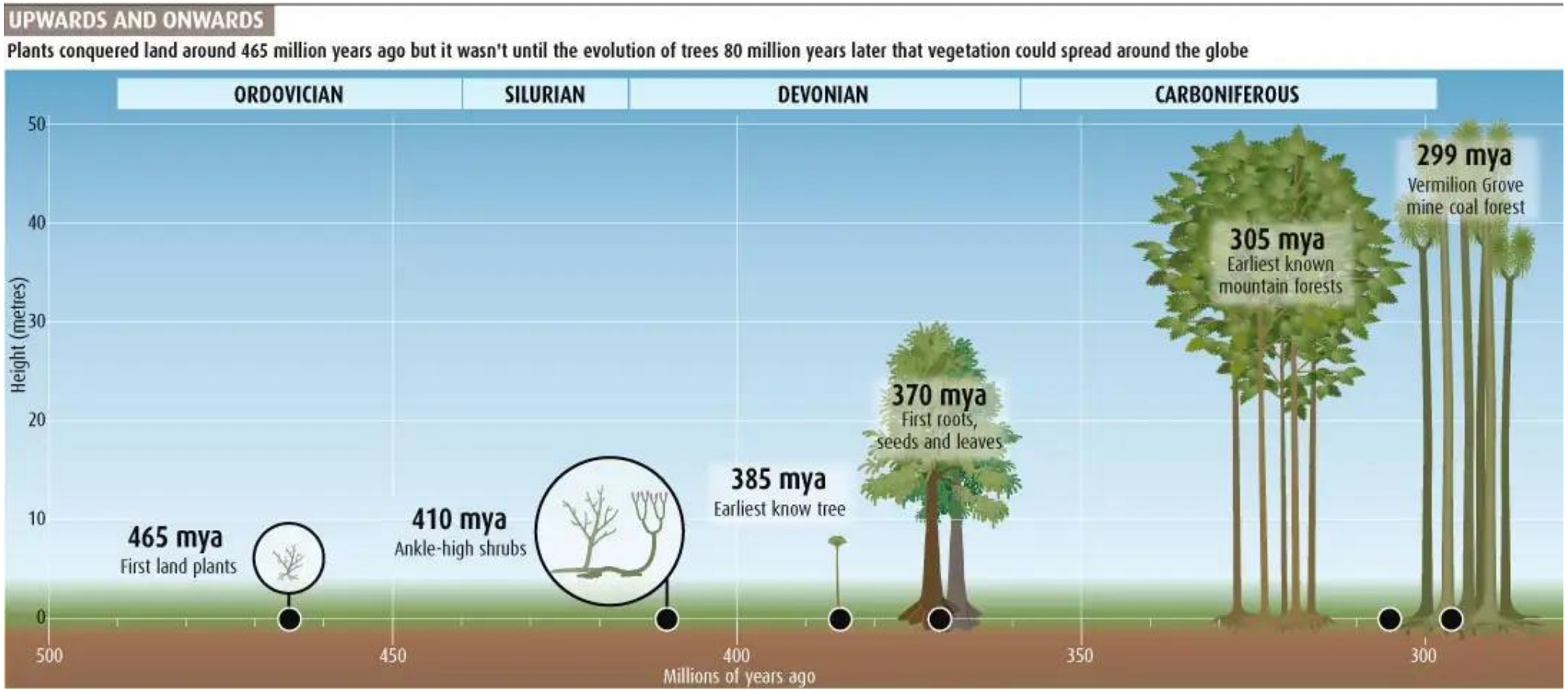
Avoided runoff: The value is based on an average volumetric charge of £1.676 per cubic metre from Scottish Water. *Scottish Water, 2024

https://www.dundee.ac.uk/corporate-information/botanic-garden-and-grounds-strategy

Dundee Botanic Garden
University of Dundee

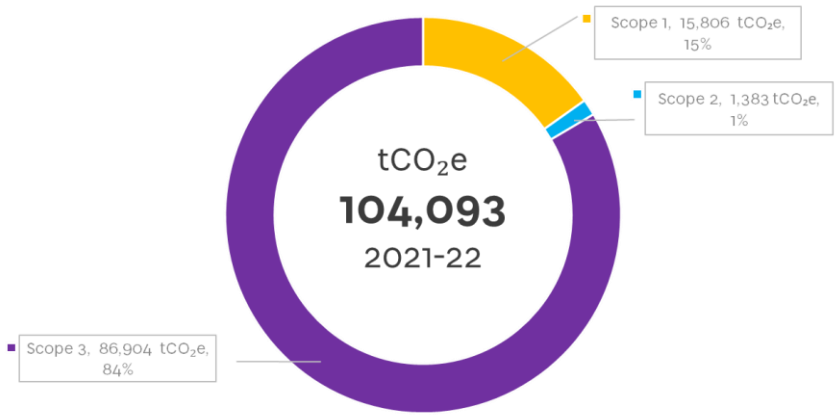
Treeconomics

Trees have changed the world before

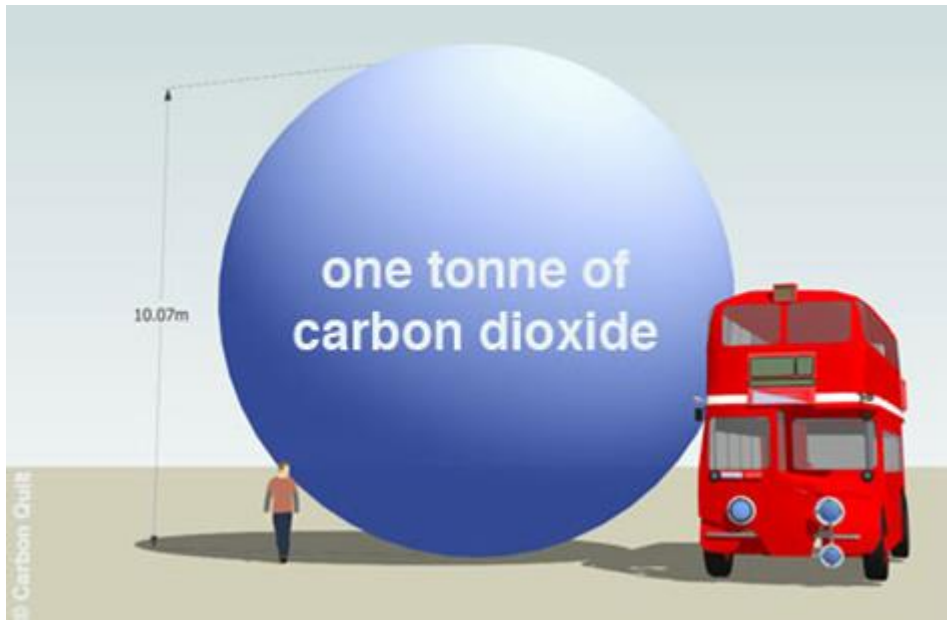


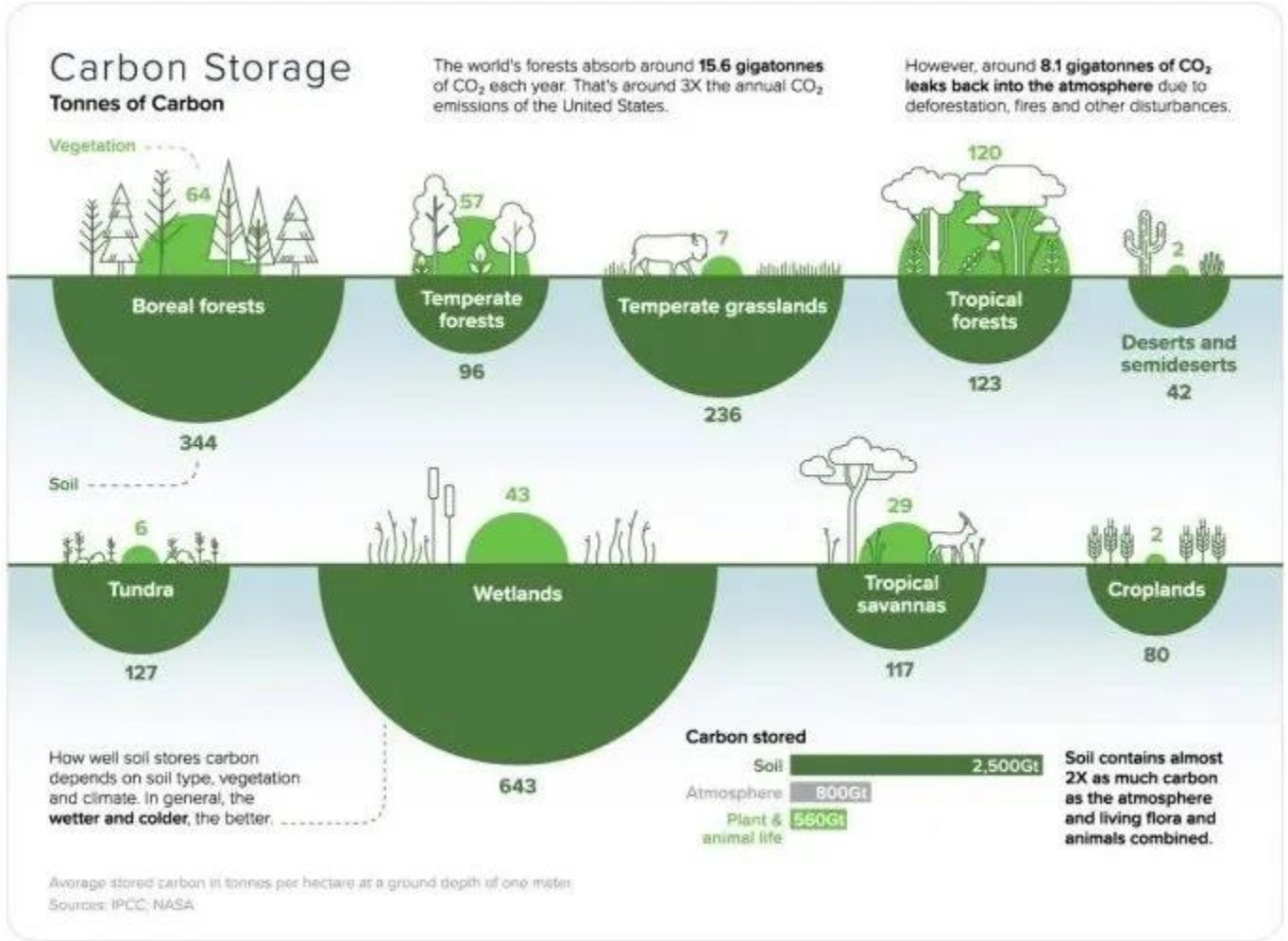
How trees changed the world By James O'Donoghue
21 November 2007

MACE Data - University-wide



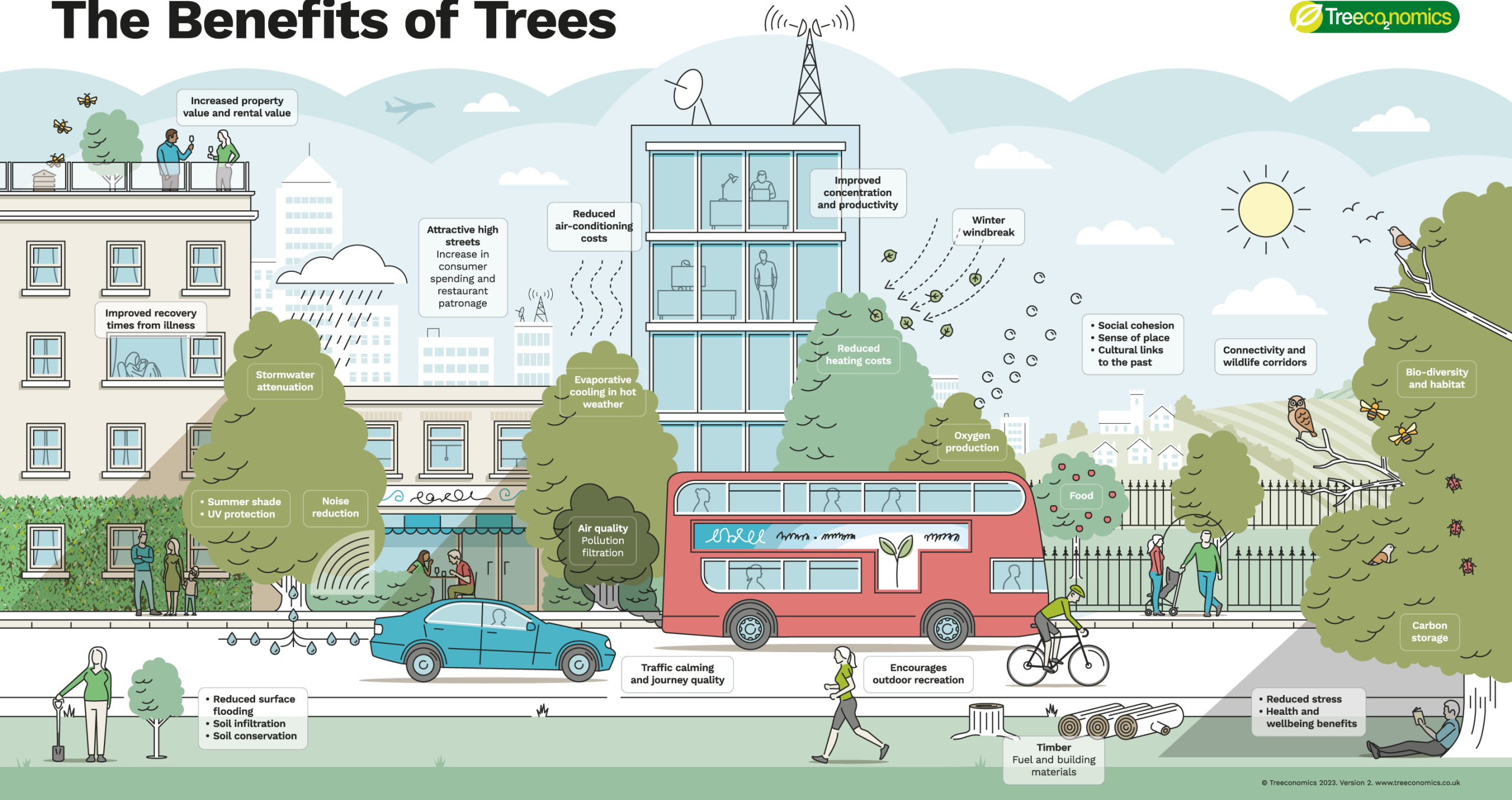
University of Dundee





The Benefits of Trees

Treeco$_2$nomics



REWILDING DUNDEE

Over the garden wall..

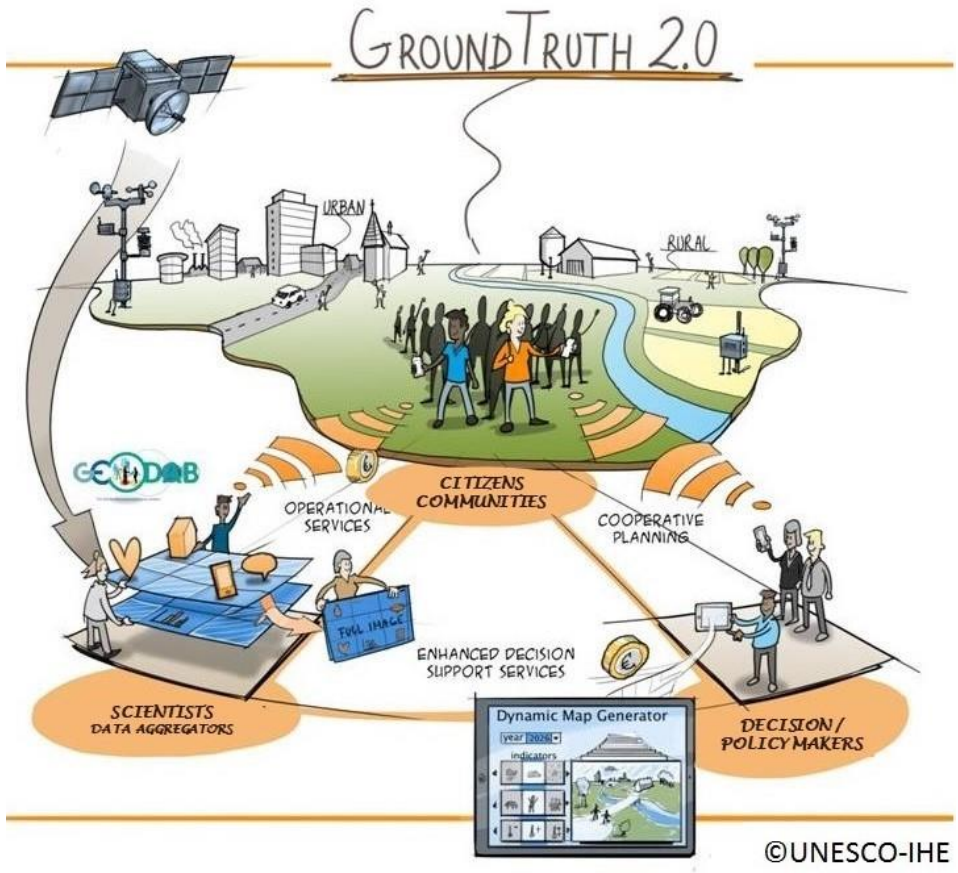
Partnering for success across the city with our community!

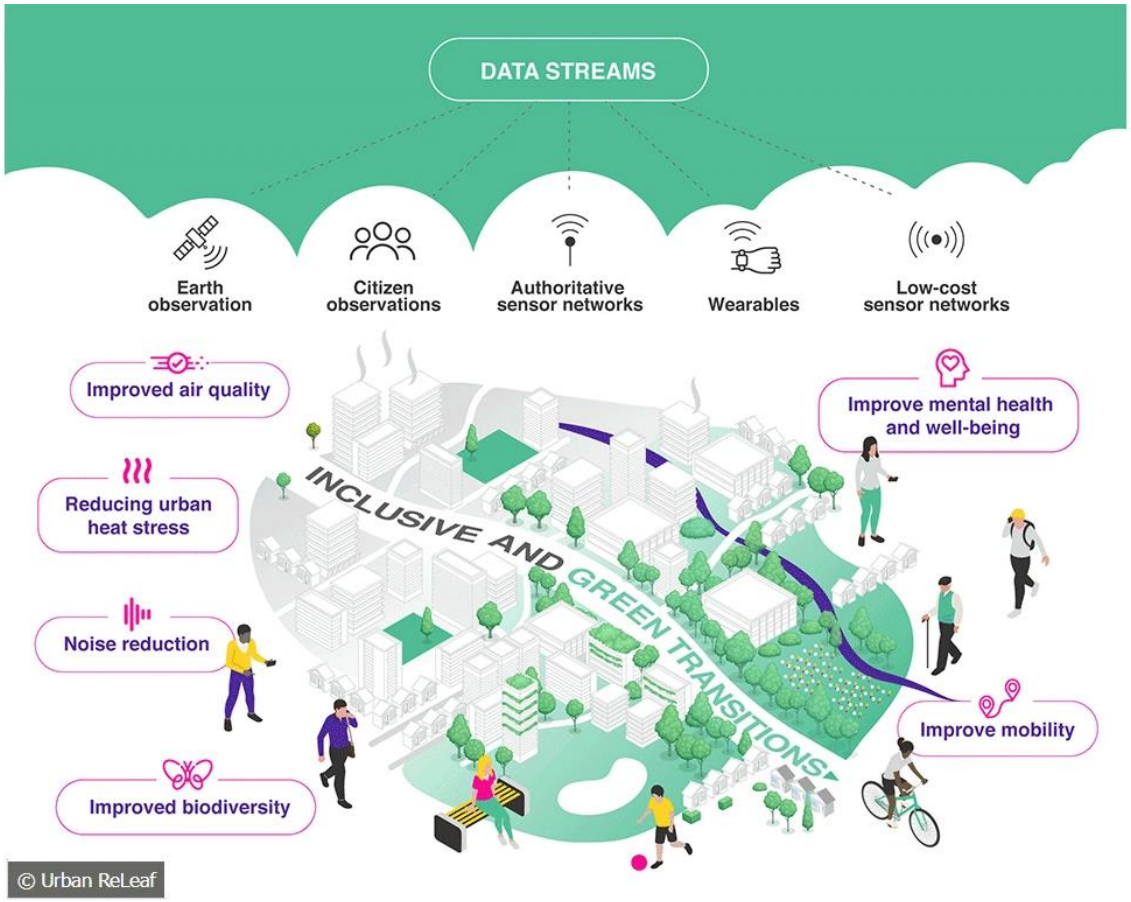
Dundee City Council

NatureScot
Scotland's Nature Agency
Buidheann Nàdair na h-Alba

NHS Tayside

Urban ReLeaf



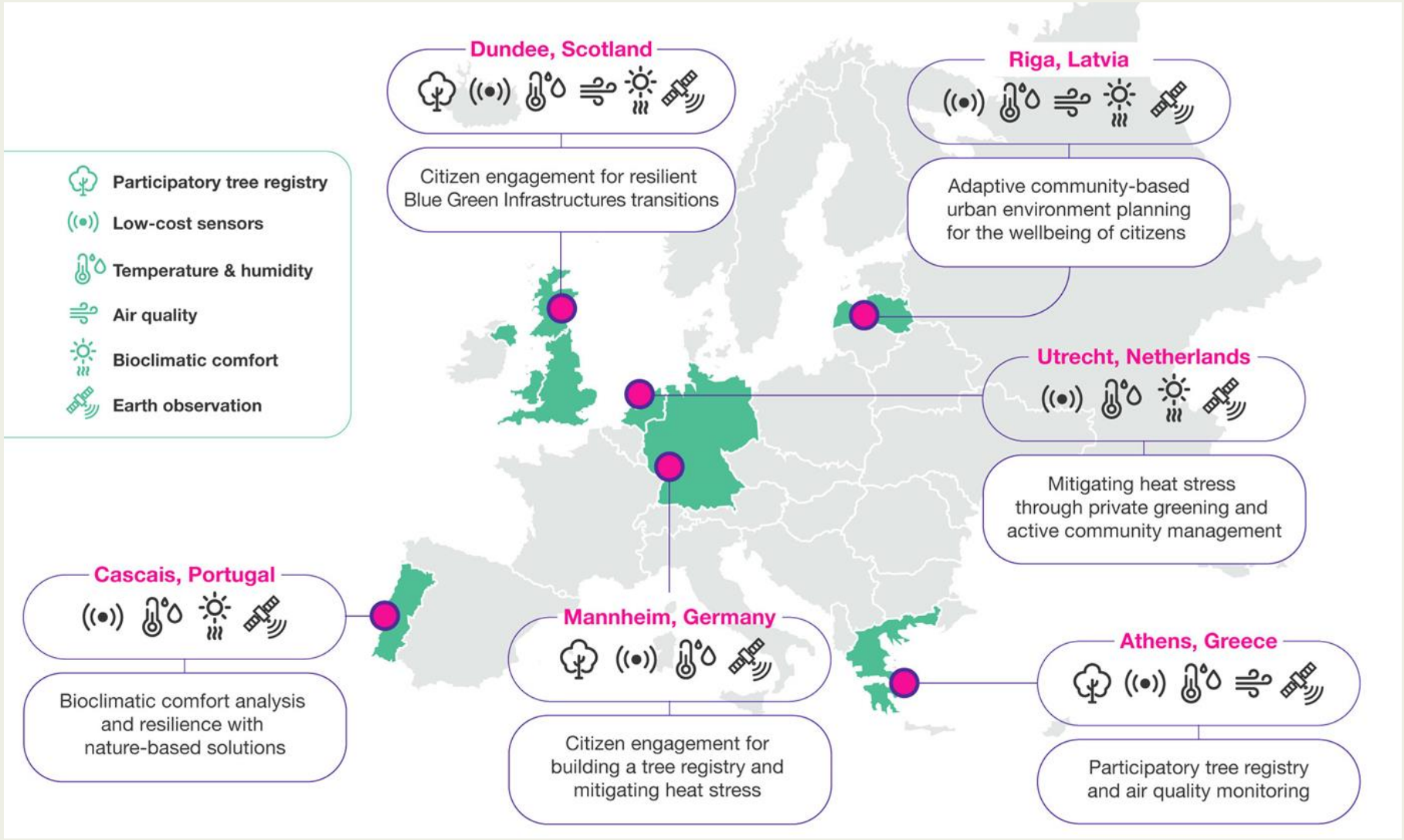


https://www.dundee.ac.uk/projects/urban-releaf

Urban Releaf

cities

- Athens
- Dundee
- Utrecht
- Cascais
- Mannheim
- Riga

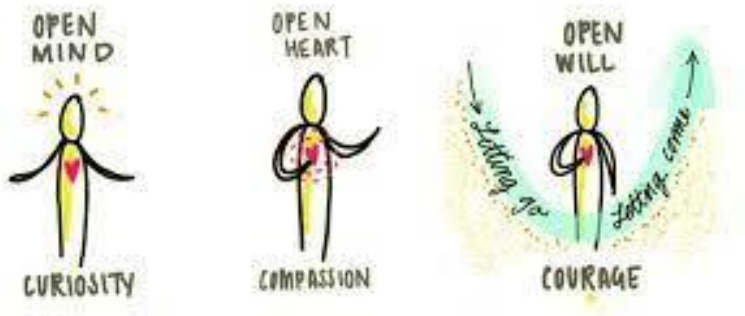


Urban Releaf

GREY TO GREEN

AND BLUE TRANSITION

- **For professionals:** engaging communities in foresight = inclusive and will result in equitable and sustainable solutions.
- **For communities:** ensures they are engaged and advocate change, beyond being listened too to become true co-designers that imagine their future, helping shape it and prepare for it.
- **For everyone:** Practicing foresight and future literacy = more resilient communities
  - Engaged in their place as active citizens,
  - Better prepared for potential disruptions,
  - Co-engaged in developing equitable pre-emptive solutions, and
  - Enabling a just transition – no one left behind.



https://urbanreleaf.eu/get-involved/

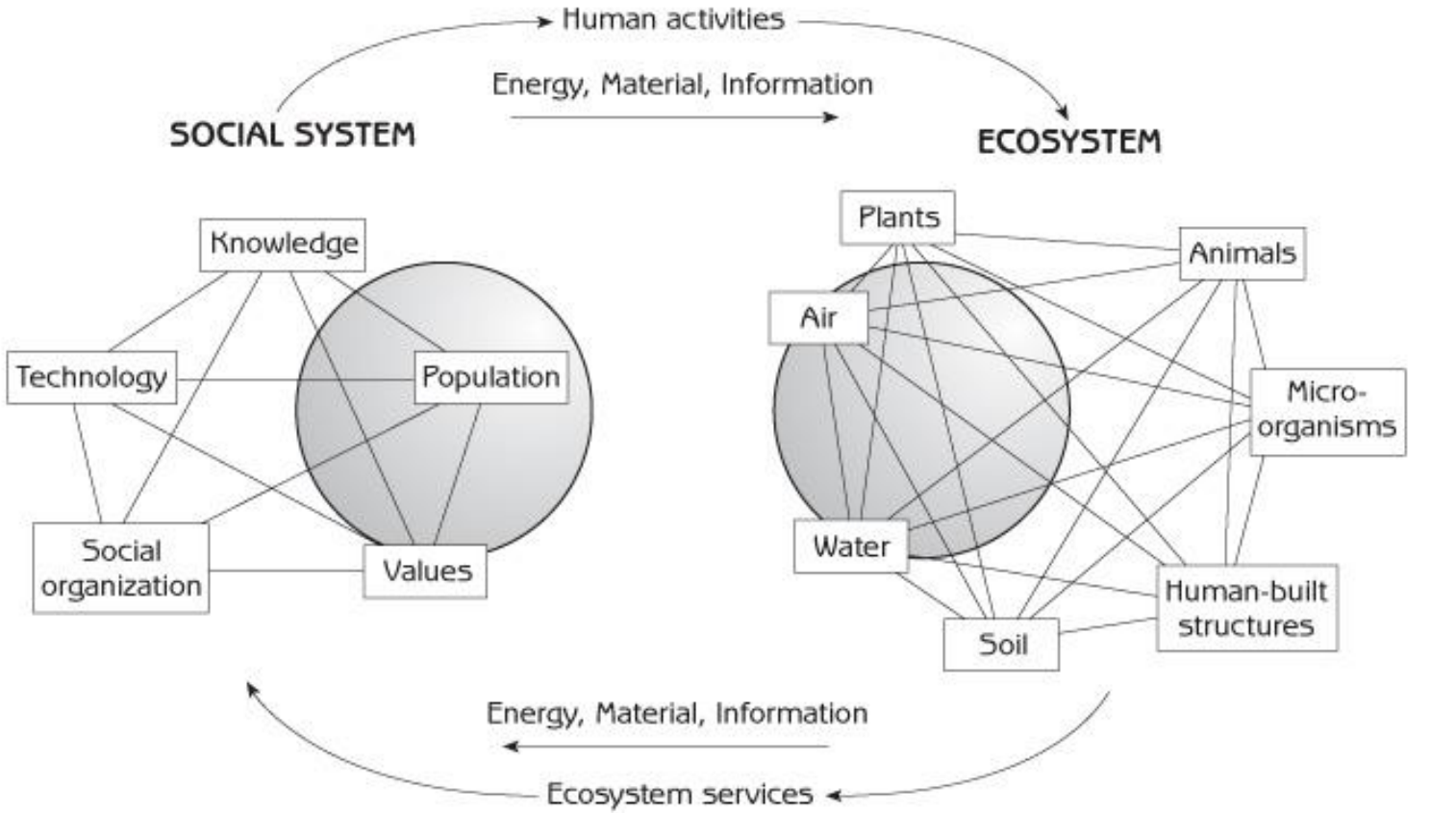
Urban regeneration

Dundee Botanic Garden
University of Dundee

Community engagement

BIG BACK GARDEN

Human ecology as a means to urban ecology



http://gerrymarten.com/human-ecology/chapter01.html


QUOTE OF THE DAY:
"DON'T CLING TO A MISTAKE JUST BECAUSE YOU SPENT A LOT OF TIME MAKING IT."
- UNKNOWN