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MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

Modelling physical processes in higher plants using leaf replicas for space applications

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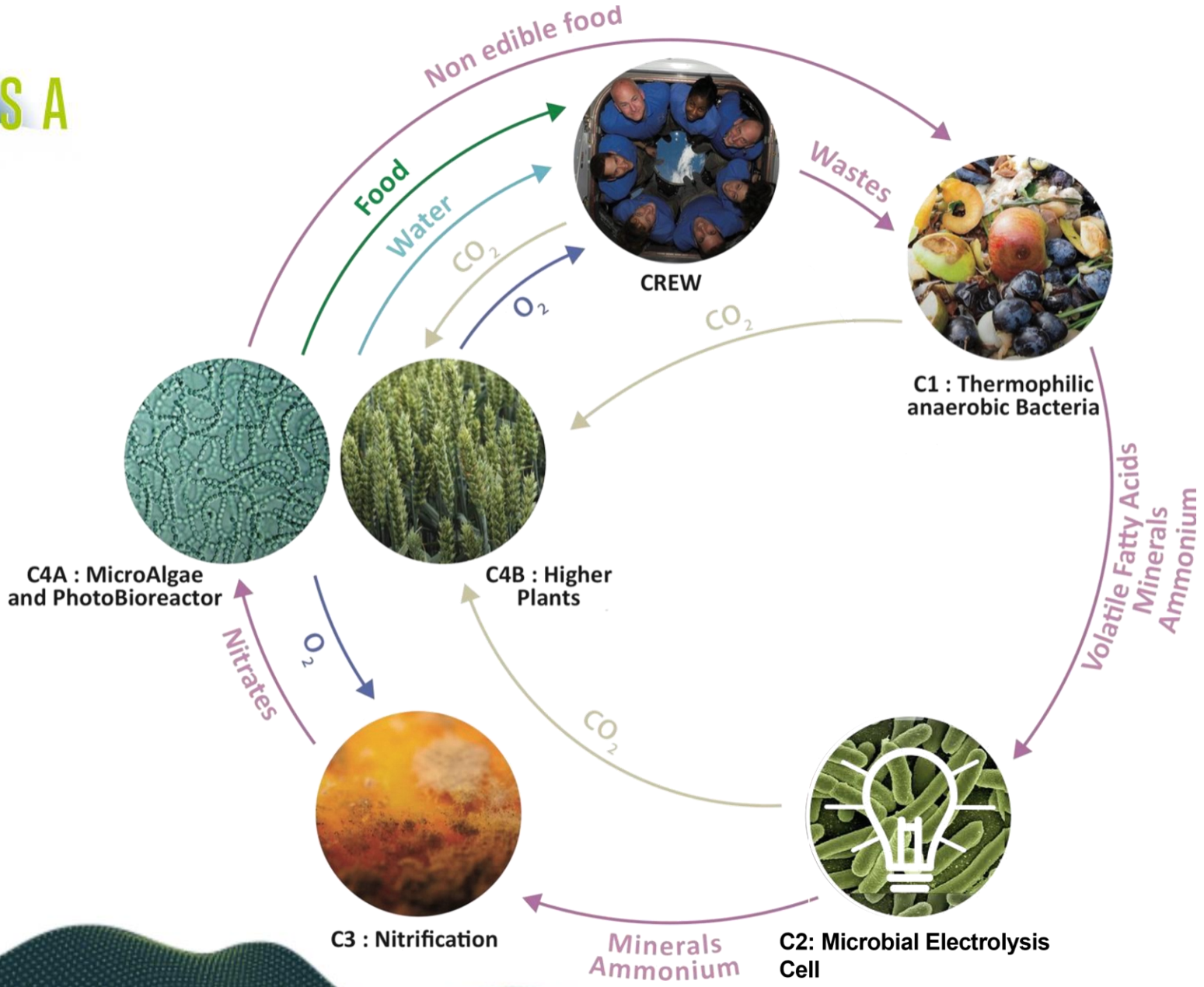
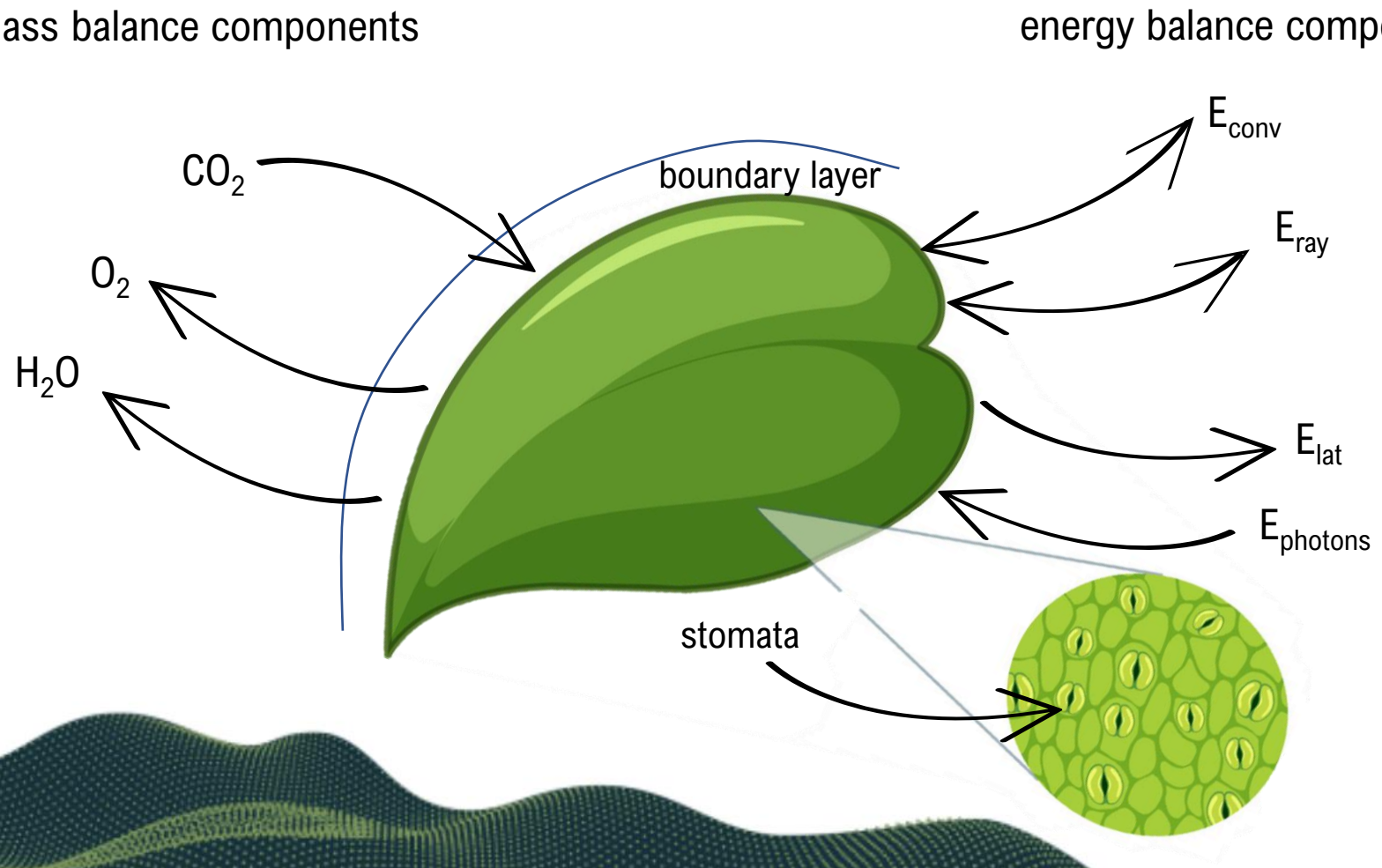

Non edible food
Food
Water
CO_2
O_2
CREW
Wastes
CO_2
C1 : Thermophilic anaerobic Bacteria
Volatile Fatty Acids
Minerals
Ammonium
C4A : MicroAlgae and PhotoBioreactor
C4B : Higher Plants
Nitrates
O_2
CO_2
C3 : Nitrification
Minerals
Ammonium
C2: Microbial Electrolysis Cell

Energy and mass balance components



Why leaf replica

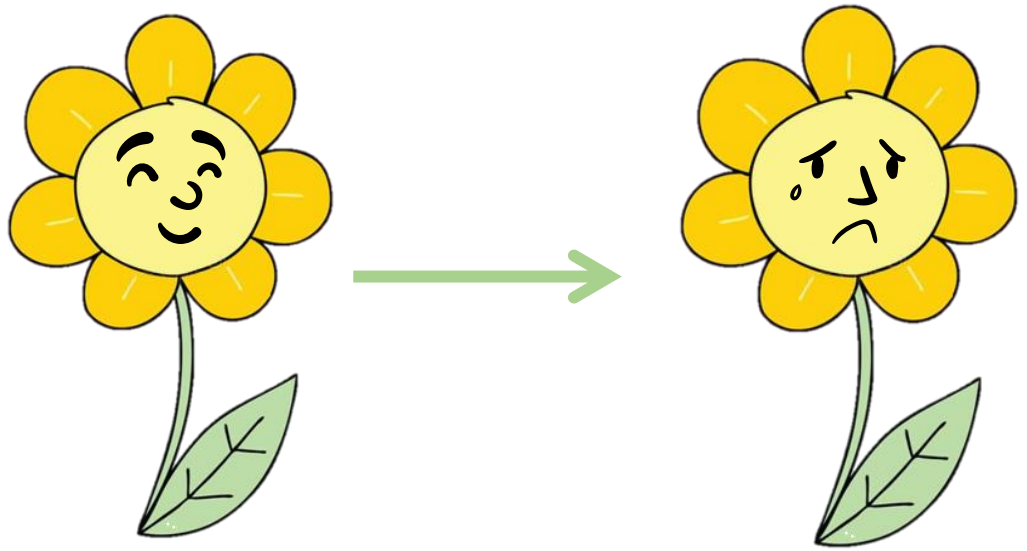
Possibility to study only the physical phenomena

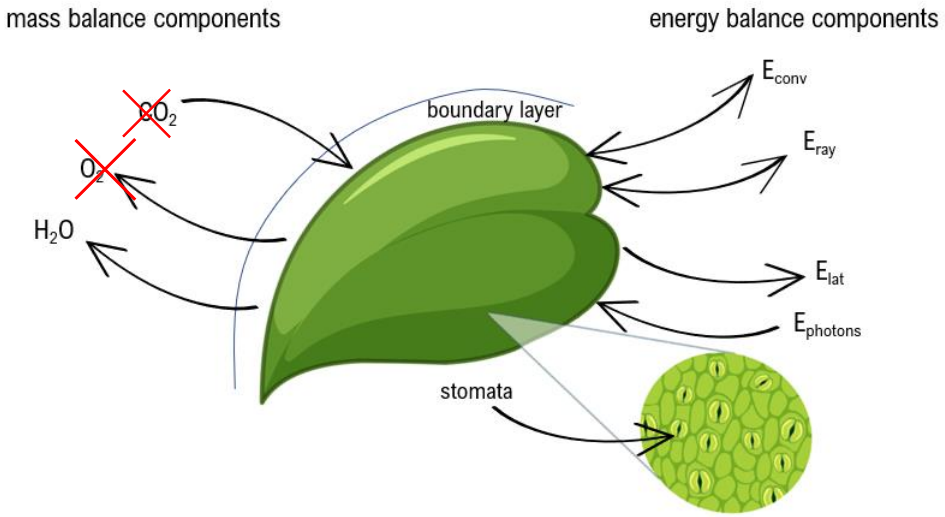
No abiotic stress

Unified size and density of stomata

Stomata always open

Small sample size can be used without compromising statistical validity





Types of the leaf replicas

Leaf replica

Simple replica

- Wet and Dry replica
- Made of single material
- Placed on the supporting structure if needed
- Shape of a studied leaf

Replica with simulated stomata

- Complex replica with few layers
- Simulated stomata with shape and size similar to the real ones
- Shape of a studied leaf/different shape

Replica with internal heating

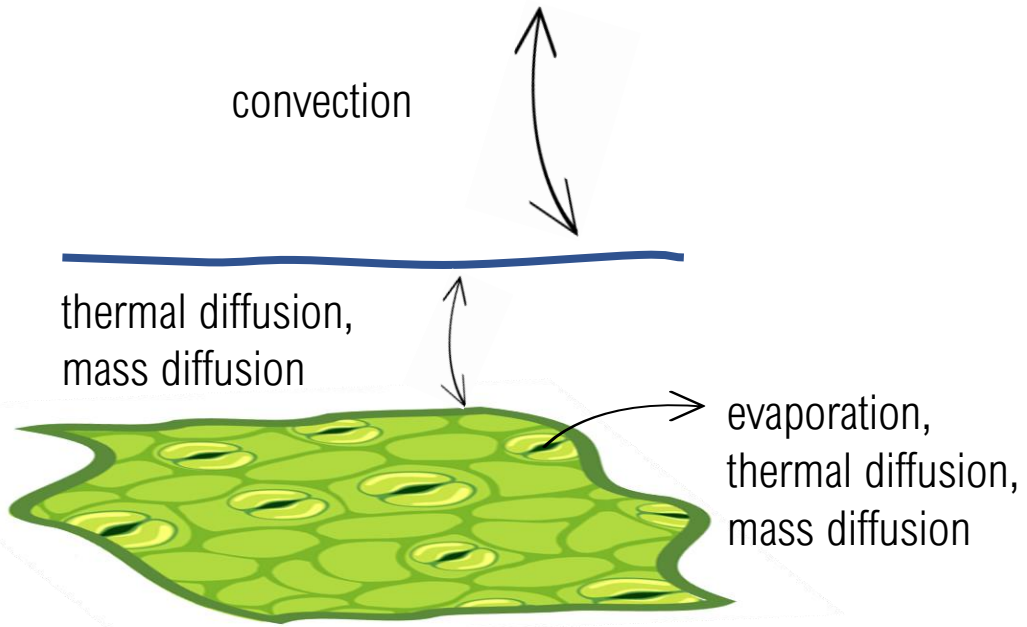
- Complex replica with few layers
- Built-in heating
- Placed on elastic structure
- Shape of a studied leaf

Physical phenomena on leaf surface

surrounding air

boundary layer

leaf surface



Dry Replica

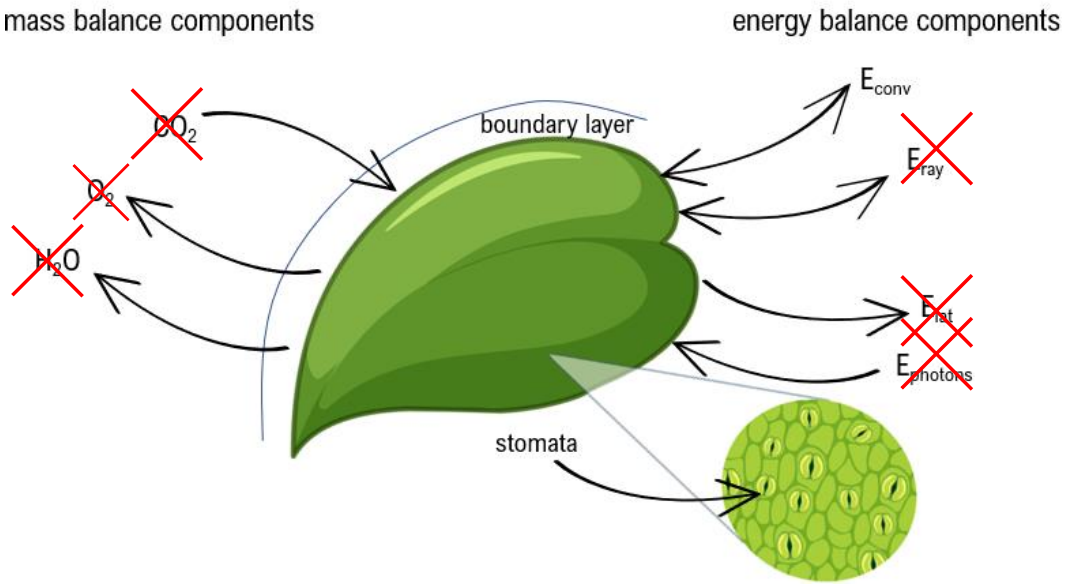
To estimate the convective heat transfer: for different airflows, leaf temperatures, gravity conditions

Mimicking the shape of real leaves

Radiative and aerodynamic properties similar to a real leaf

Used with external energy source

Used material: copper, brass sheet, Perspex or aluminium sheet



Two dry replicas

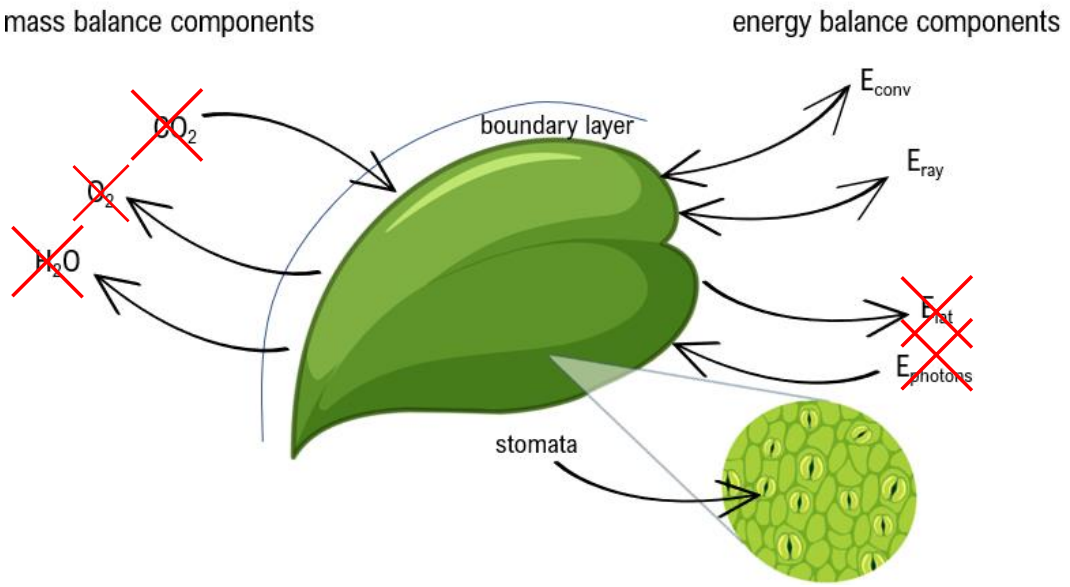
To estimate boundary layer parameters

The same thermal properties

Covered with the different colour (for example black and white)

Used to calculate boundary layer conductance in dynamic conditions

Used with external energy source



Wet replica combined with dry one

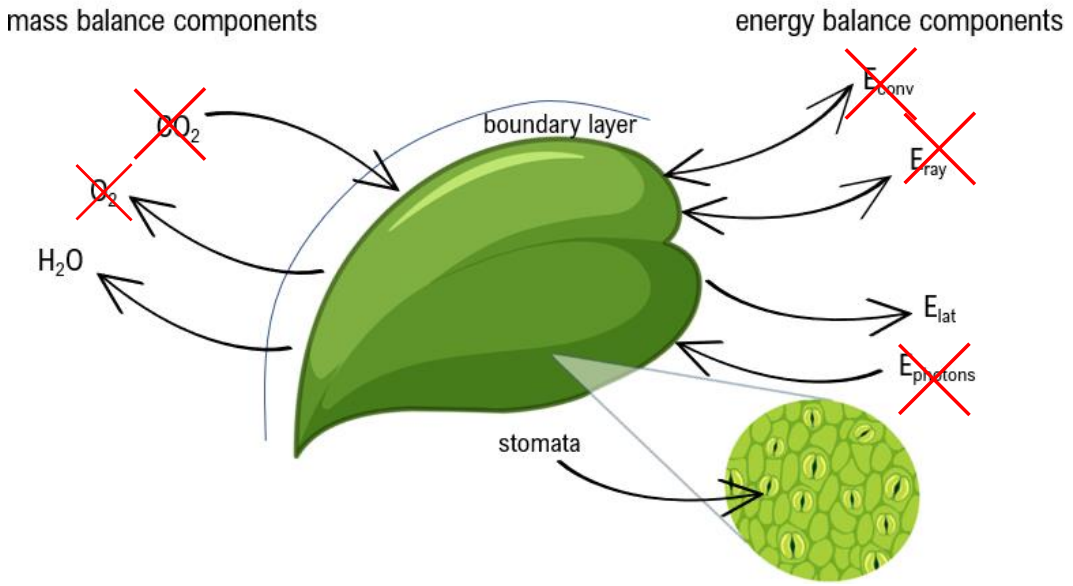
To estimate latent flux

Similar thermal capacity

Used with external energy source

Used for different airflows, leaf temperatures, gravity conditions

Wet cloth or paper and placed on a supporting structure



Replica with *stomata type 1*

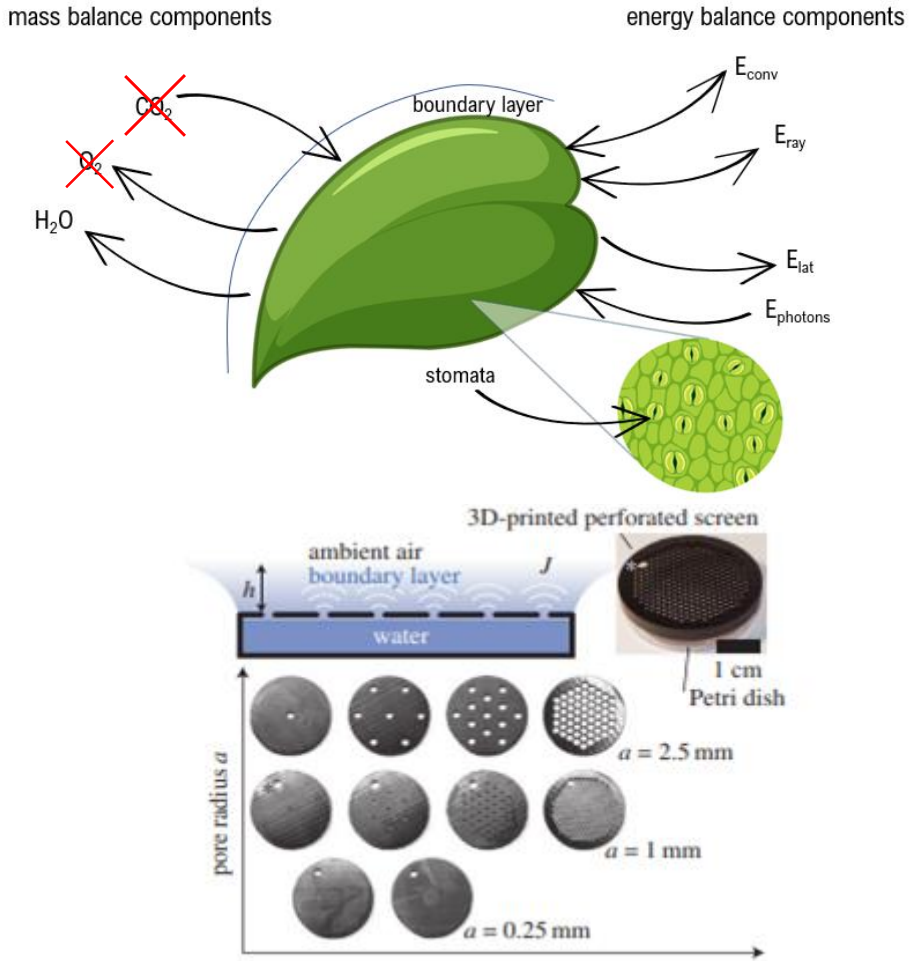
To estimate latent heat flux more accurately

Different thermal capacity compare to real leaf

Used with external energy source

Used to estimate the latent heat flux depends on size and density of the stomata

Usually made using petri dish or other small vessel with a micro-perforated foil, or a plate placed on it



M.A. Zwieniecki, K.S. Haaning, C.K. Boyce, K.H. Jensen, Stomatal design principles in synthetic and real leaves, J. R. Soc. Interface. 13 (2016) 20160535

Replica with *stomata type 2*

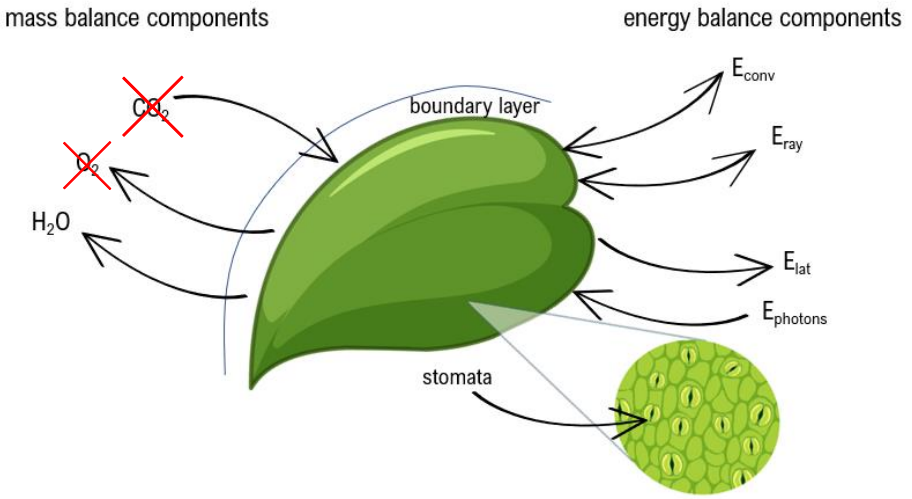
To estimate latent heat flux together with energy balance

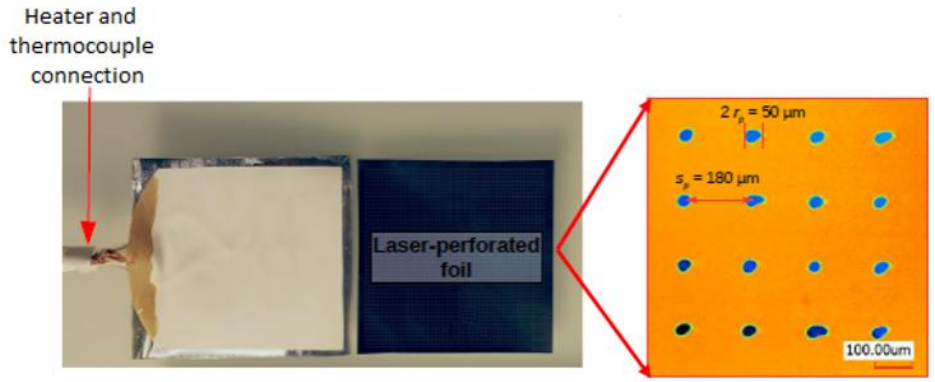
Similar thermal capacity to real leaf

Used with external energy source

Used to estimate the latent heat flux depends on size and density of the stomata

The transpiring side of the leaf was covered with a wettable fabric enclosed in a microporous sheet with the water supply connected to it





S.J. Schymanski, D. Breitenstein, D. Or, *Technical note: An experimental set-up to measure latent and sensible heat fluxes from (artificial) plant leaves*, Hydrol. Earth Syst. Sci. 21 (2017) 3377–3400.

Heated replica

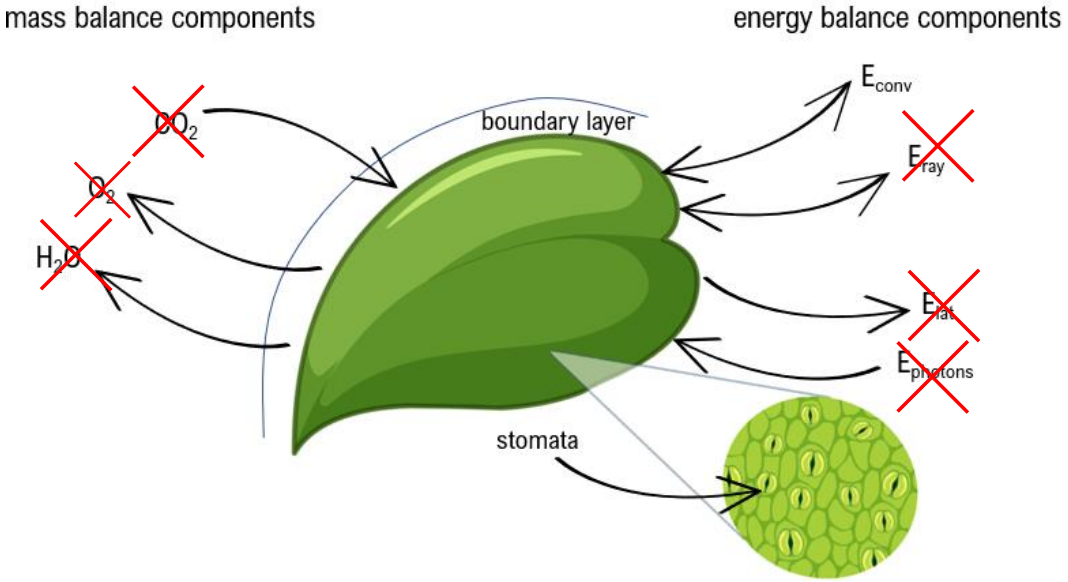
To estimate the boundary layer conductance

Used with internal energy source

In between the sheets or on the bottom part the heaters were glued

Used in a field and in a controlled environment

Made of highly polished brass sheets, flexible Mylar1 sheet



Summary:

Energy balance	Dry and wet replica	Transpiration studies	Wet replica
	Heated replica		Dry and wet replica
	Replica with stomata		Replica with stomata
Boundary layer	2 dry replicas		
	Dry and wet replica		
	Heated replica		
	Replica with stomata		

Conclusions

Understanding physical processes on the leaf level is crucial for the development of the mechanistic model.

It creates possibility to test the models without biological processes included

Ones it is understood it can be scaled at the whole canopy in order to use knowledge-based description of mass, heat and energy exchange instead of empirical model

Such an approach will contribute to a better understanding of biological processes in plants later on

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THANK YOU.

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