Evolutionary drivers of stomatal size and density

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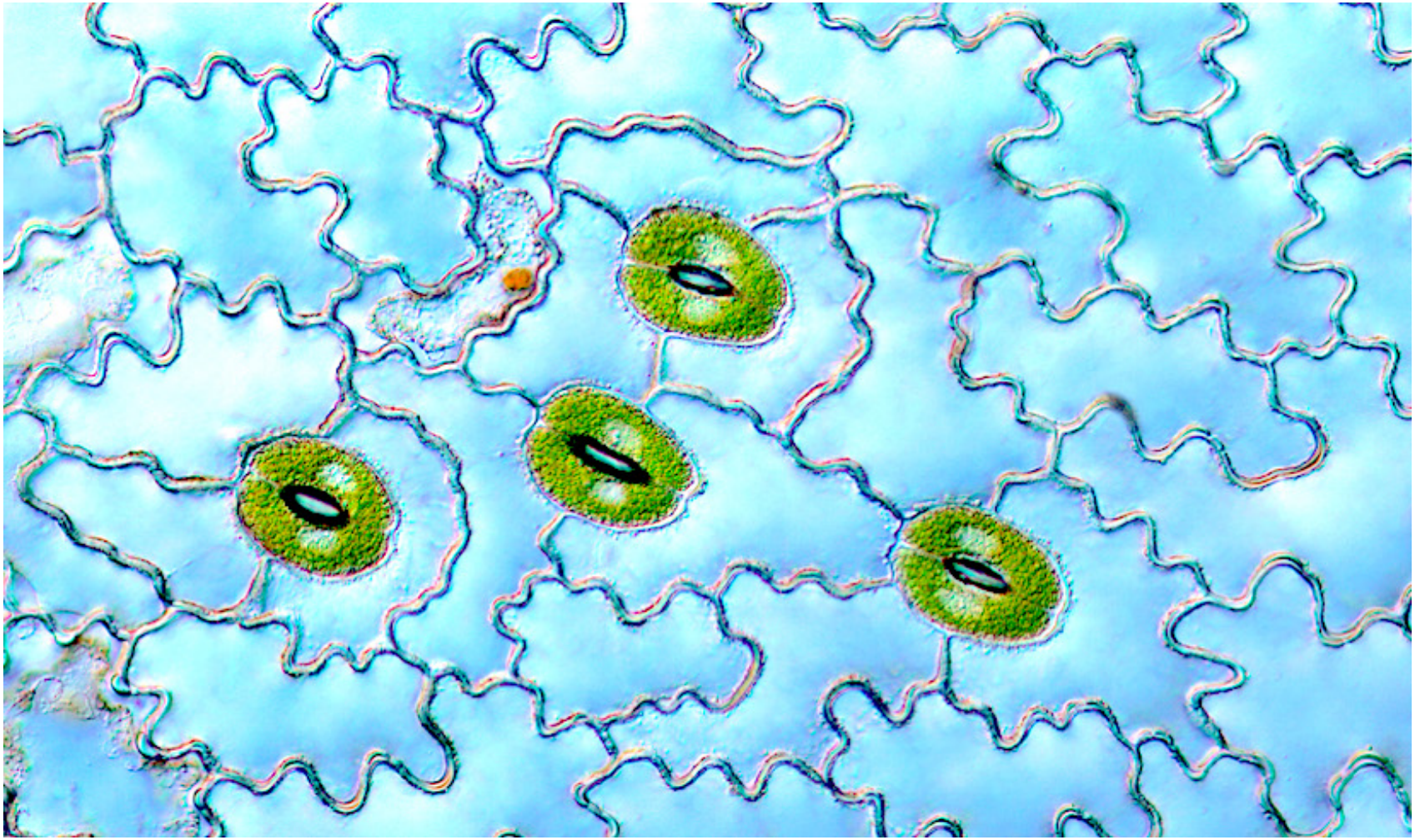
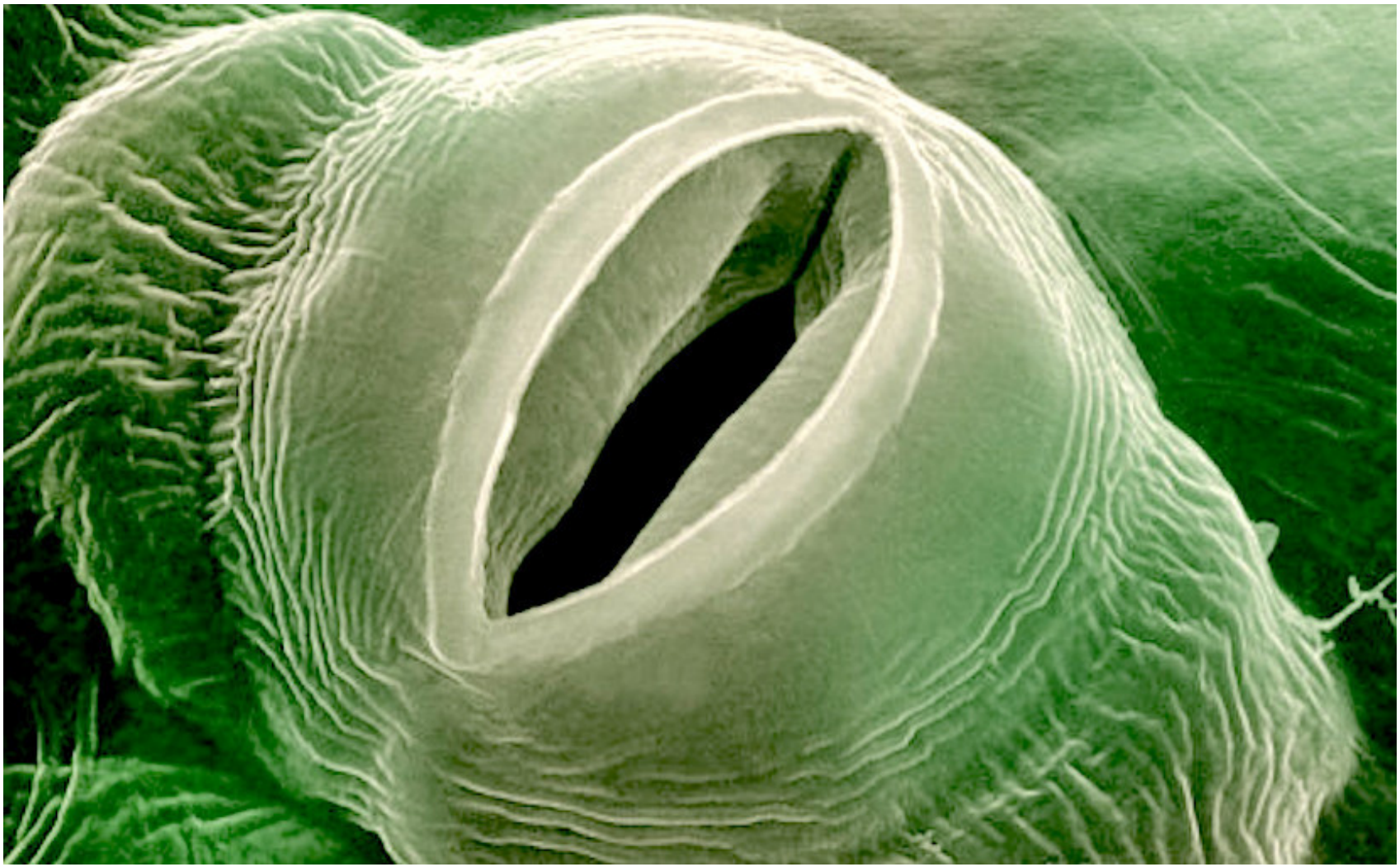
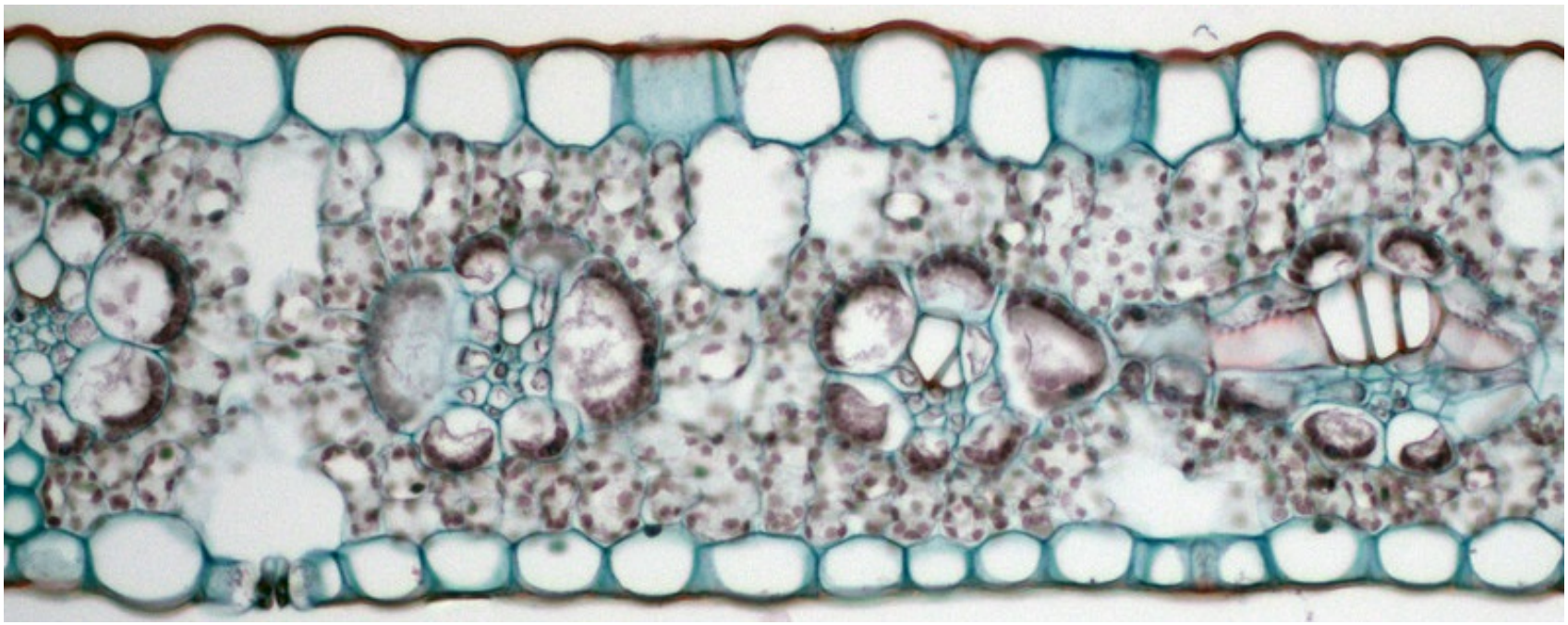
What is a stoma



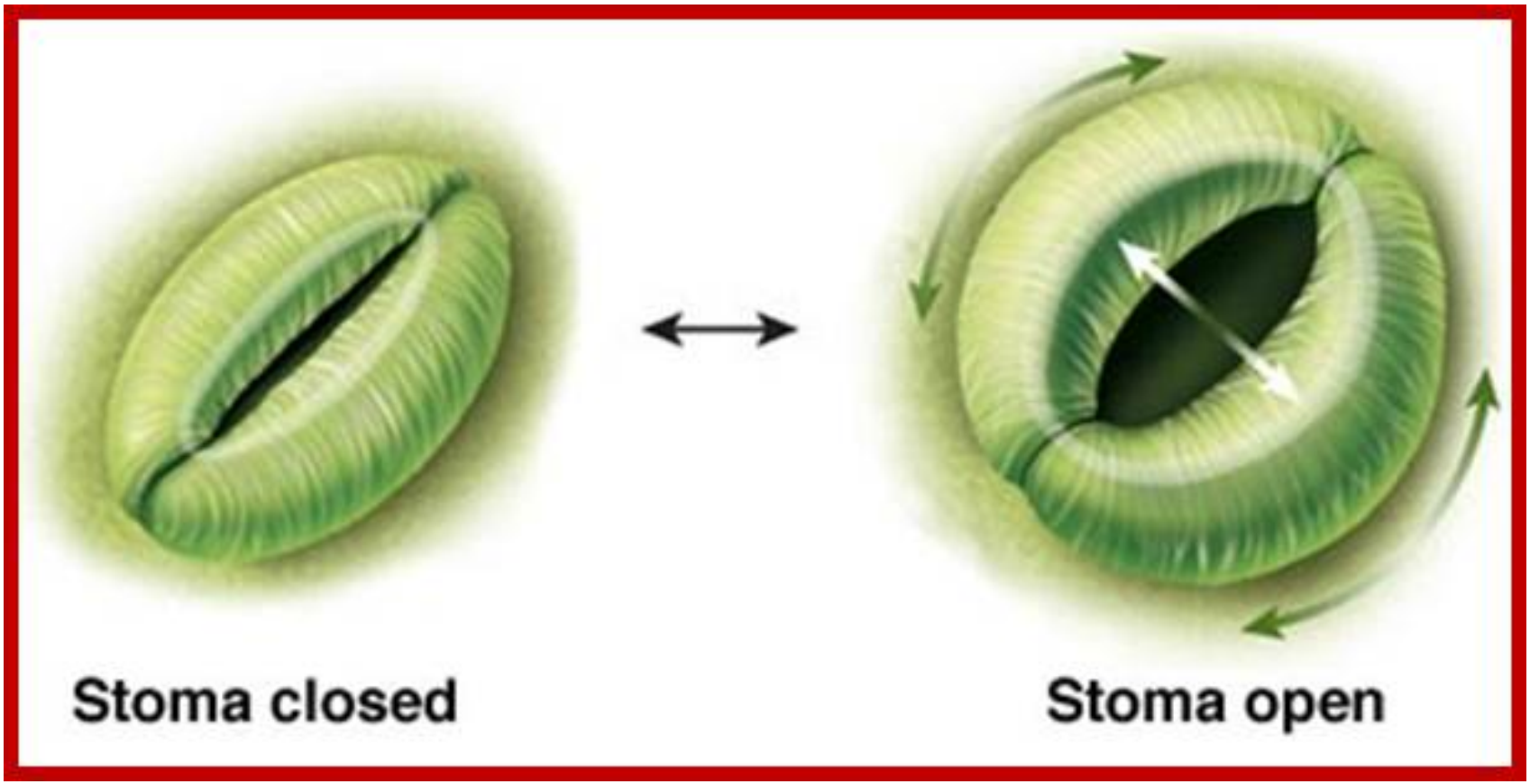
What is a stoma



Why land plants need stomata



Short-term response

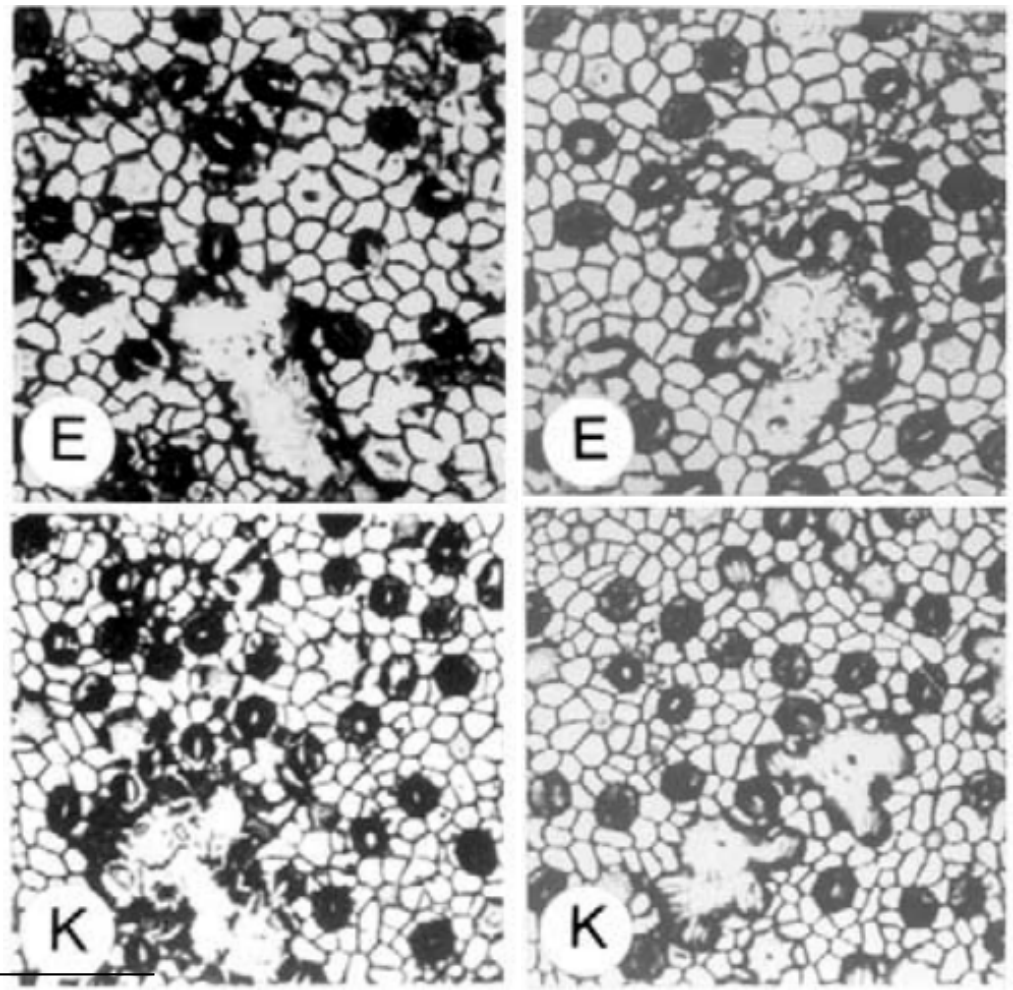


Long-term response

Stomatal size and density versus drought stress[1]

E
Irrigated

K
Stressed



[1] Bosabalidis and Kofidis, 2002

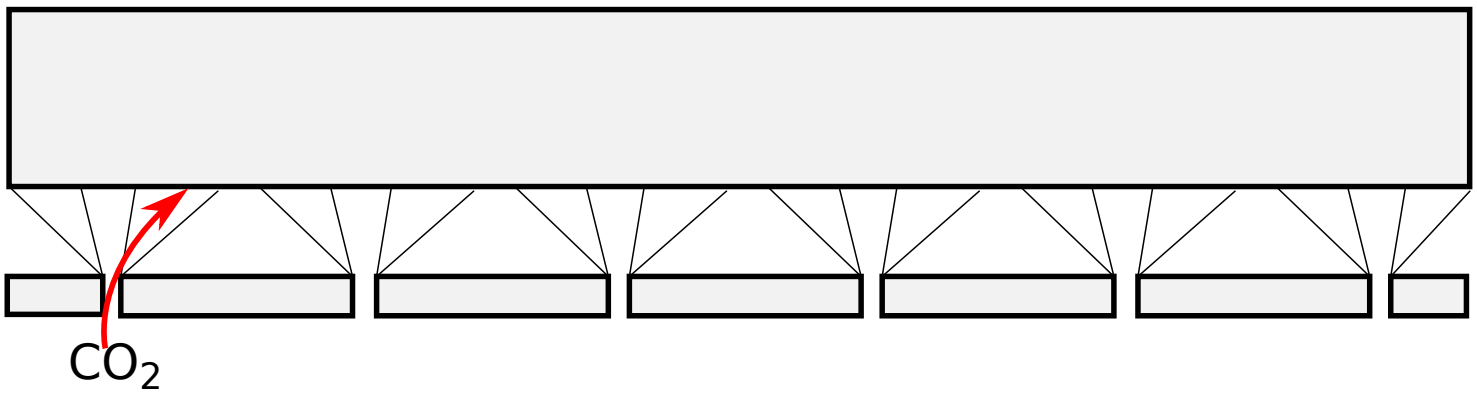
WHY?

Hypothesis 1 – Response time

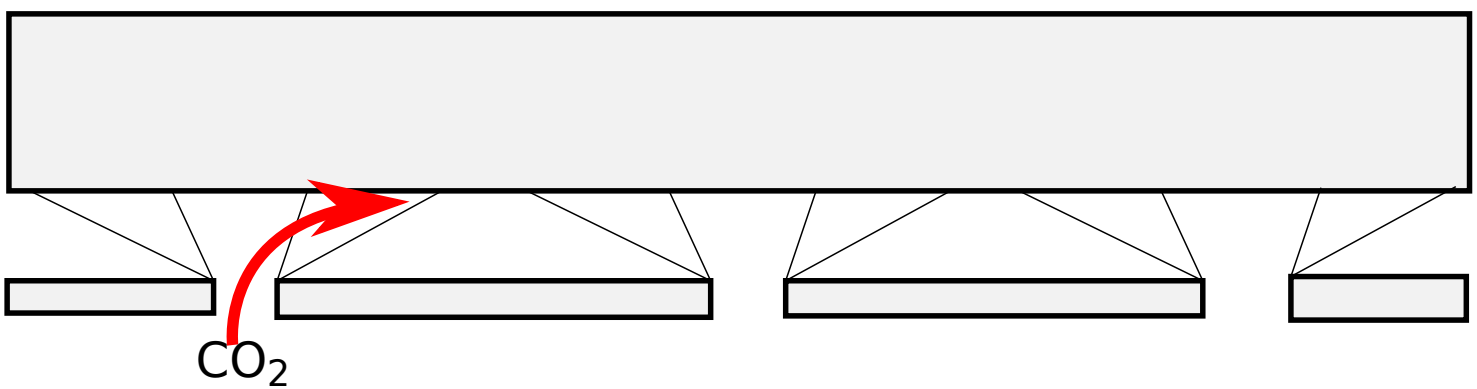
Smaller stomata respond faster

- Smaller volume and faster response time;
- Favored by any plant;
- Only valid under rapid environment changes;

Hypothesis 2 – Trade-off

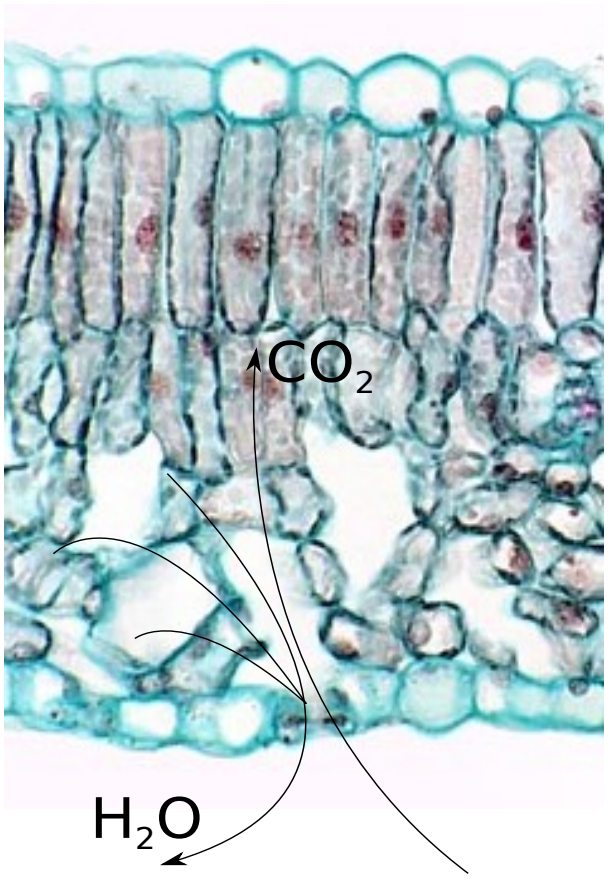


Smaller stomata : shorter distance for diffusion

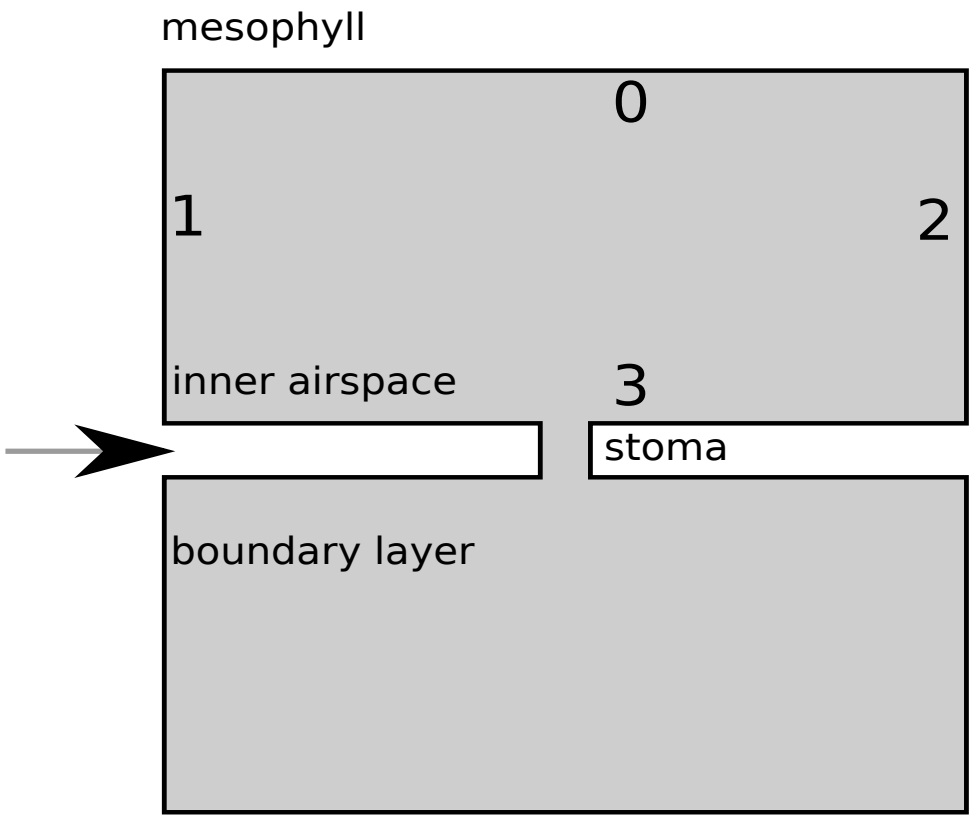


Bigger Stomata : higher diffusion rate per stoma

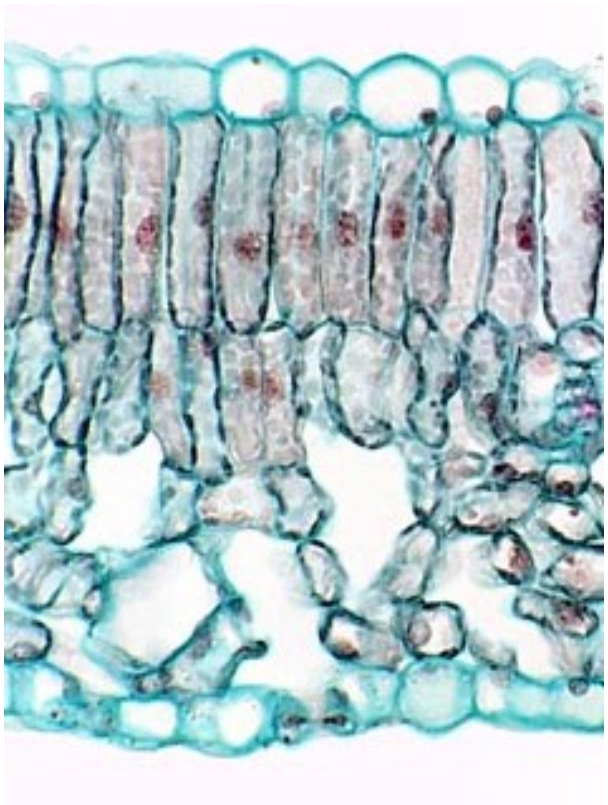
Simplified stomatal model

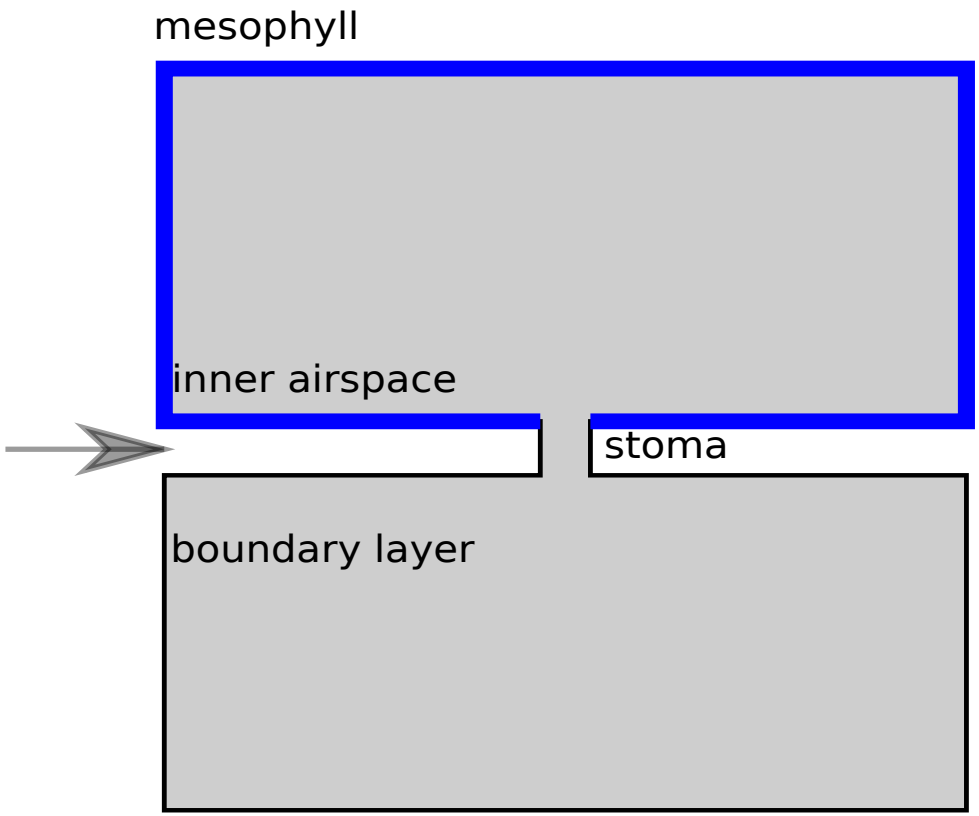


G_H=Transpiration/D
G_C= G_H/1.6

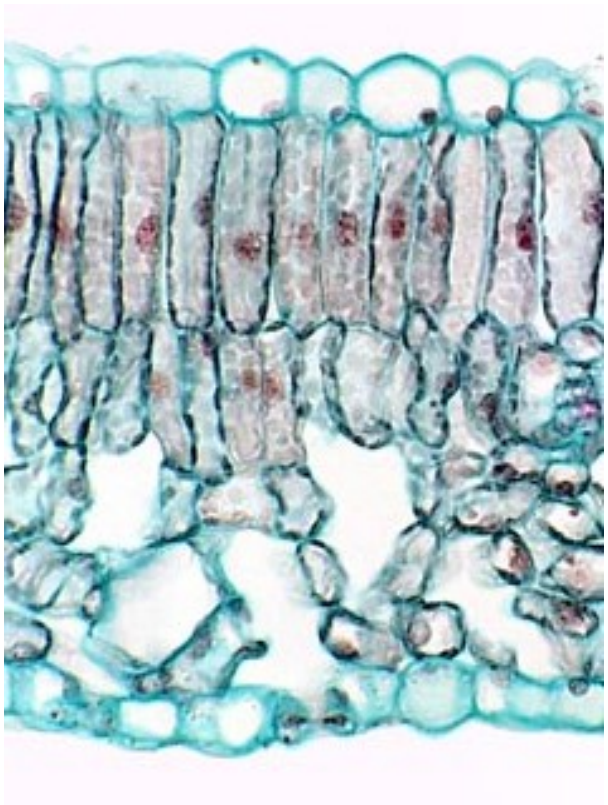


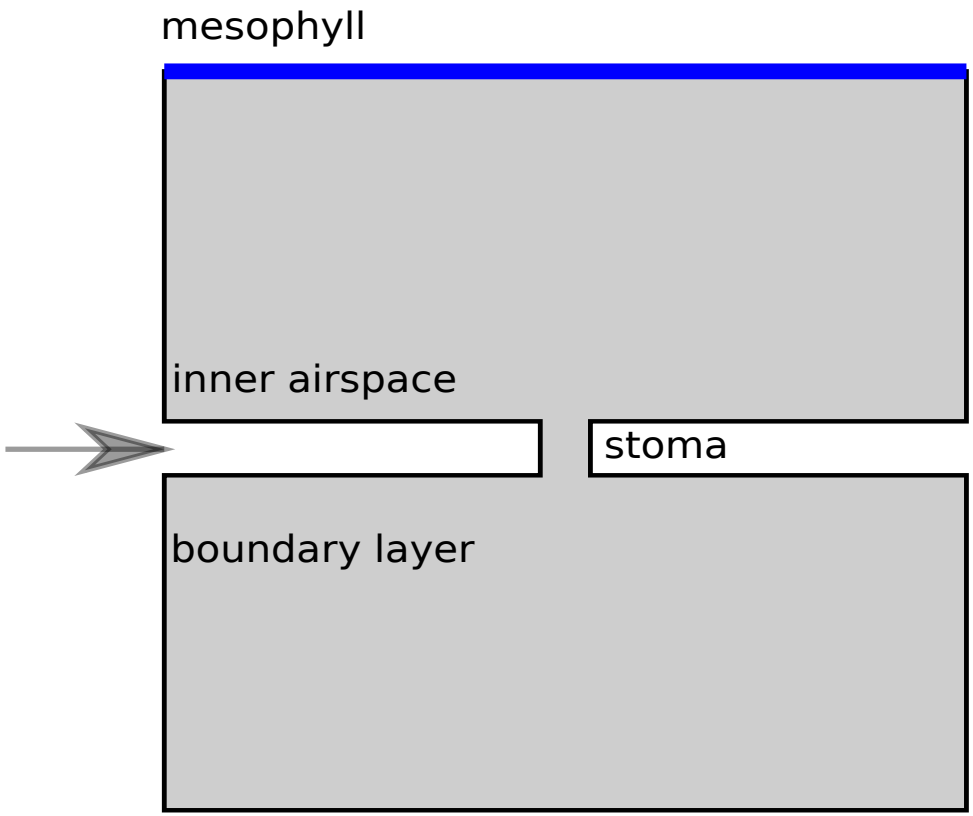
Simplified stomatal model



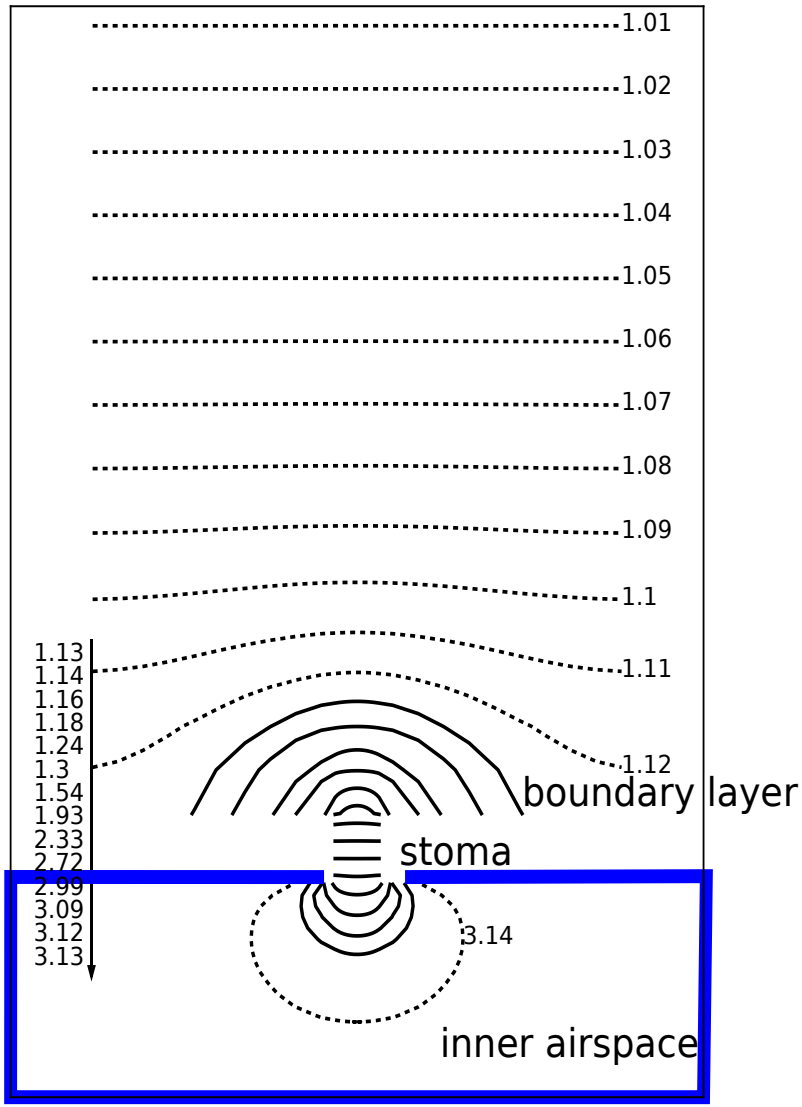


Simplified stomatal model

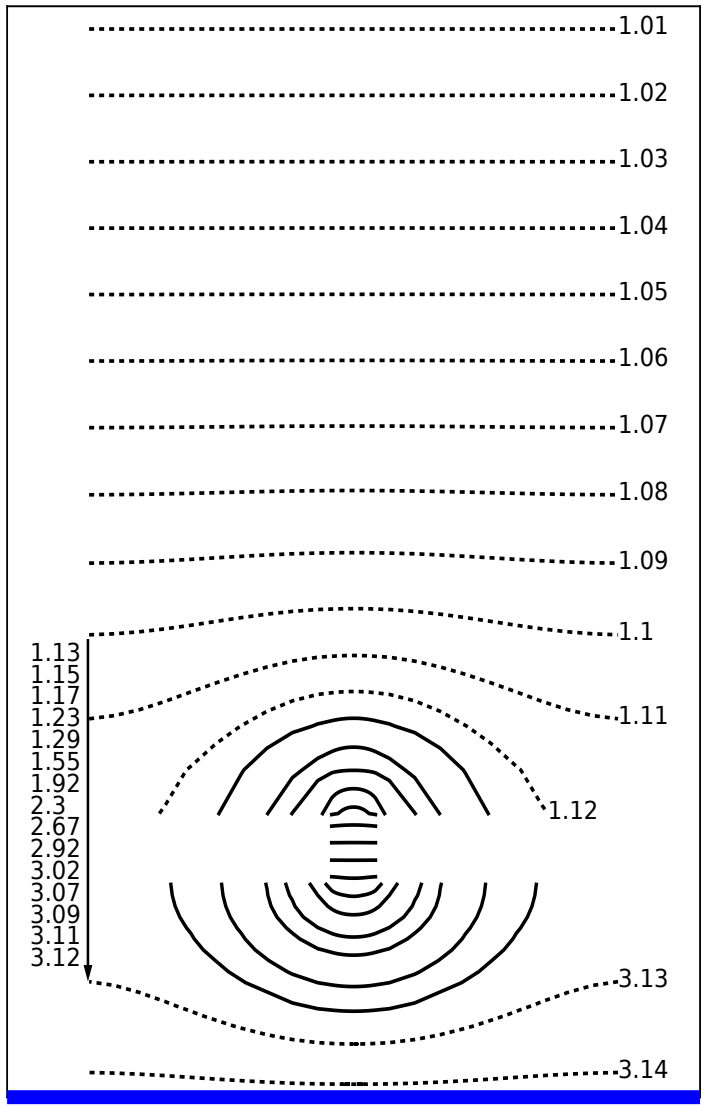




Converted Senario



Model Scenario



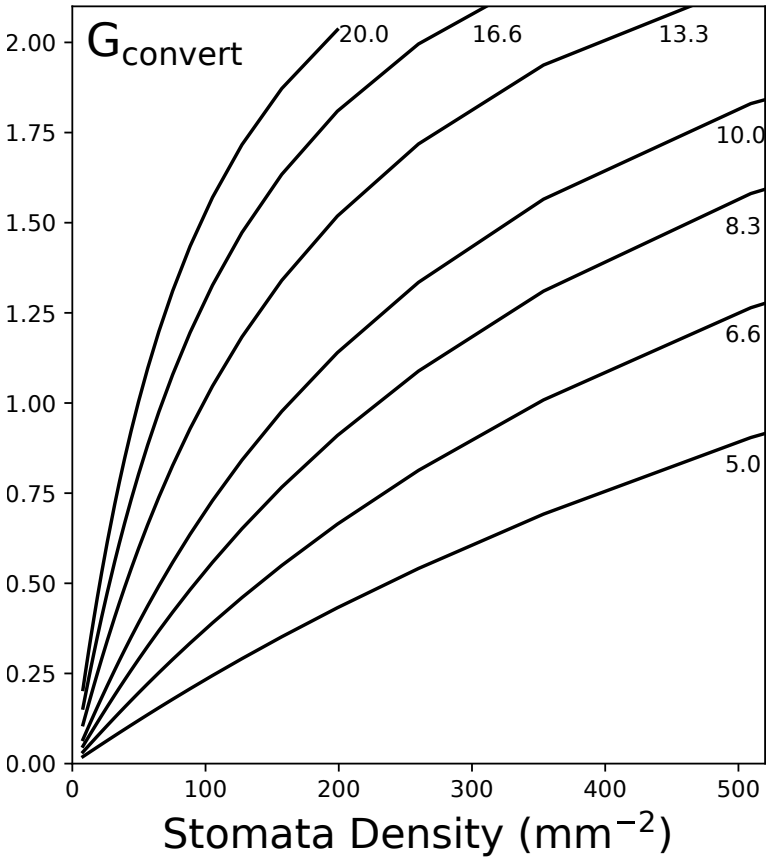
Gas exchange simulation

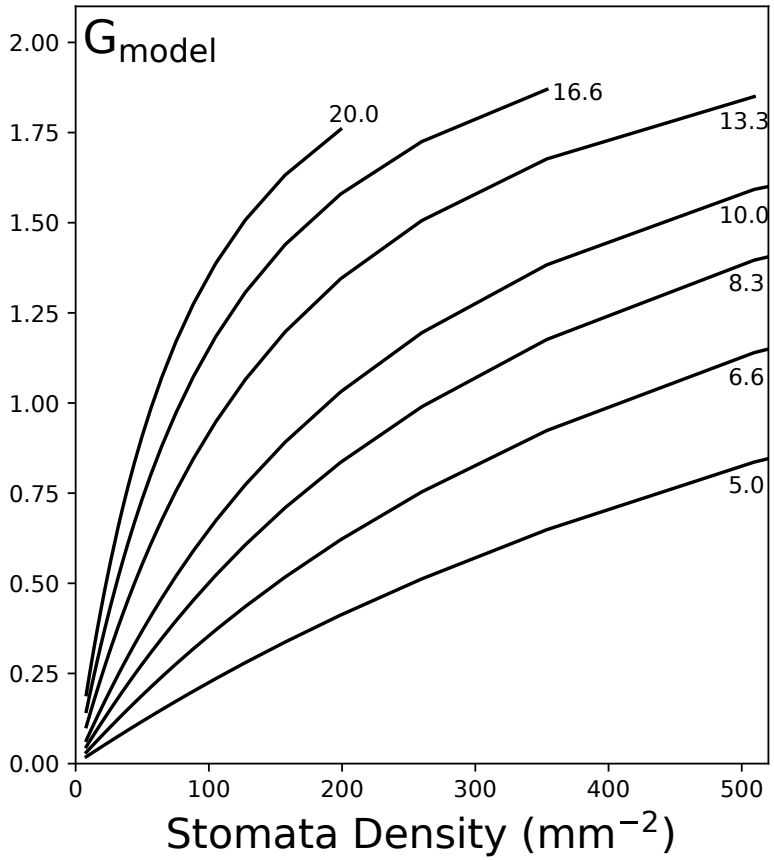
G_{convert} Leaf conductance of $\mathrm{H_2O}$ from all wet surface;

G_{model} Leaf conductance of $\mathrm{H_2O}$ from mesophyll surface;

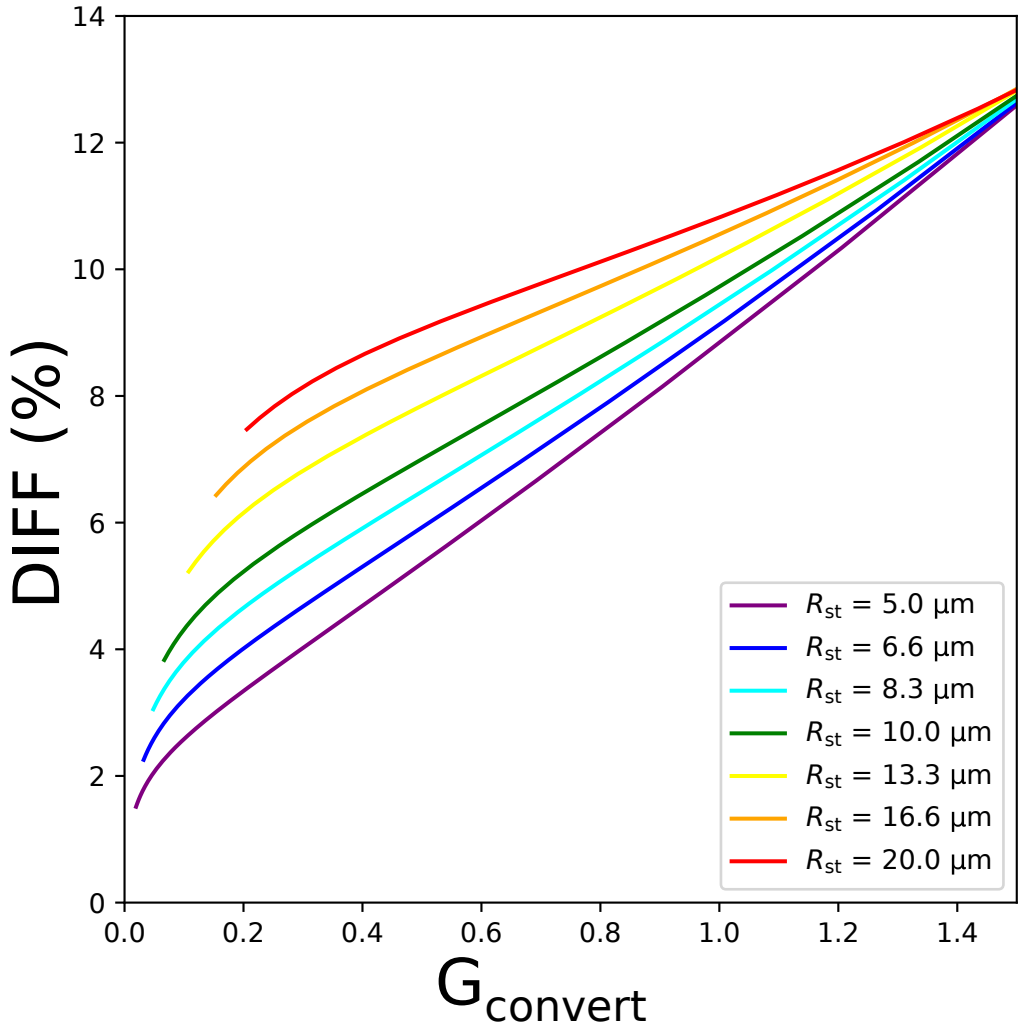
DIFF $G_{\text{convert}}/G_{\text{model}} - 1$;

Simulation results





Simulation results



Model conclusion

Smaller and higher density stomata

At the same transpiration rate:

- Higher G_{model};
- Faster response time;

Hypotheses

Hypothesis 1 Invalid;

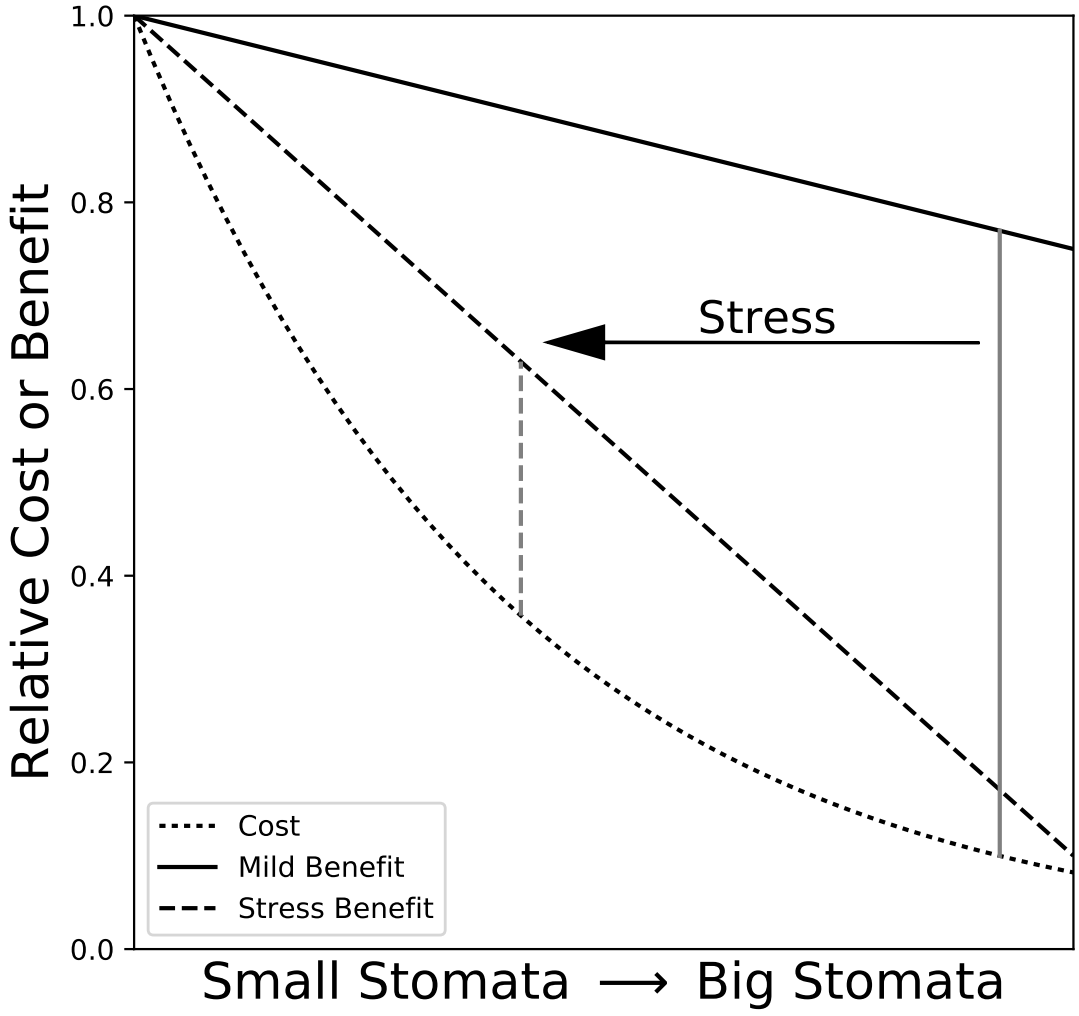
Hypothesis 2 Invalid;

What is the COST of smaller stomata?

Cell construction

- Total number of cells $\propto$ $(\textit{Cell size})^{-3}$;
- Cell wall area per cell $\propto$ $(\textit{Cell size})^{2}$;
- Total cost in cell wall per volume $\propto$ $(\textit{Cell size})^{-1}$.

Cost and benefit analysis



Conclusion

- Smaller stomata are more efficient;
- Smaller stomata have higher construction cost;
- The trade-off of construction cost and water use efficiency is the driver of stomatal size and density.

“Side-effects”

DIFF influences the computation of photosynthesis-related parameters, such as:

- C_{i};
- G_{C};
- G_{M};
- δC^{13}.

Acknowledgments

Supervisory Committee

- John Sperry
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