2-D Photosynthesis Model

We model leaf photosynthesis using a two-dimensional porous medium approximation. The model is solved using a finite element method (FEM) in the *R* package **deSolve** (**soetaert2010?**). Table 1 is a glossary model terms and symbols. Here we describe the model and associated *R* code.

## Leaf anatomy

We assume that the leaf is a homogenous 2-D medium. In the final version, we will incorporate differences in spongy and palisade porosity, gradients in light absorption, electron transport capacity, and Rubisco concentration. The mesophyll is thick and the stomata are regularly spaced apart by distance on both ab- and adaxial surfaces. In this scenario, we assume that the stomata on each surface are precisely offset from each other by distance . This minimizes the average distance between any point in the mesophyll and its nearest stomate. Because of the regular spacing, we only need to model the region between a stomate on surface and the next stomate on the other surface (fig. 1). The rest of the mesophyll will be the same because of symmetry.

## Code

I’ve copied the *R* code to set up the model and solve it if you want to copy and paste on your own machine. First, here are the packages you’ll need.

library(dplyr)  
library(ggforce)  
library(ggplot2)  
library(readr)  
library(tidyr)

|  |
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| Figure 1: Example leaf anatomy analyzed by the 2-D FEM. |

| Name | Symbol | Value | Units | Notes |
| --- | --- | --- | --- | --- |
| [CO] in substomatal cavity |  |  | mol m leaf | assumed |
| [CO] compensation point |  |  | mol m stroma | Caemmerer (2000) |
| Diffusivity of [CO] in intercellular airspace | $D\_ |  | m s | assumed |
| Conductance of cell wall, plasmalemma, cytosol, chloroplast envelope, and chloroplast stroma |  |  | m m stroma s | Evans et al. (2009) |
| Maximum photosynthetic e transport rate on a leaf area basis |  |  | mol m leaf s | assumed |
| Catalytic rate of Rubisco |  |  | m | Tholen and Zhu (2011) |
| Rubisco effective |  |  | mol m | Caemmerer (2000) |
| Number of elements in direction |  |  | NA |  |
| Number of elements in direction |  |  | NA |  |
| Fraction of intercellular airspace (aka porosity) |  |  | m airspace m leaf | assumed |
| Volumetric respiration rate |  |  | mol m stroma s | Earles et al. (2017); Tholen and Zhu (2011) |
| Leaf surface area-to-mesophyll surface area ratio |  |  | m mesophyll m leaf | assumed |
| Tortuosity of intercellular airspace |  |  | m m | Syvertsen et al. (1995) |
| Stroma volume-to-mesophyll surface area ratio |  |  | m stroma m mesophyll | Earles et al. (2017); Tholen and Zhu (2011) |
| Rubisco concentration in stroma |  |  | mol m stroma | Tholen and Zhu (2011); Oguchi, Hikosaka, and Hirose (2003) |

## References

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