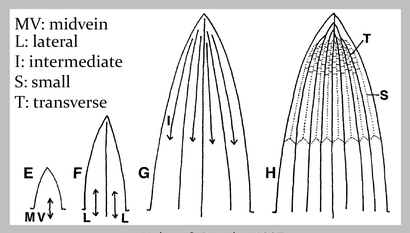
Developmental Dynamics of Maize Leaf Vascular Patterning

Diana Ruggiero
PhD Adviser: Samuel Leiboff
Oregon State University, Department of Botany and Plant Pathology

Vein Density: A Key Trait for Photosynthetic Efficiency

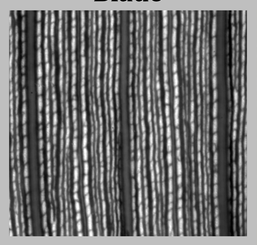
Maize performs C_4 photosynthesis, a more efficient process than the C_3 pathway used by most plants. C_4 photosynthesis is underpinned by a specific vascular architecture known as Kranz anatomy, characterized by high vein density.

My projects seek to identify genetic regulators of vein patterning in the maize leaf. These genes are potential targets for improving yield and drought tolerance in crops.

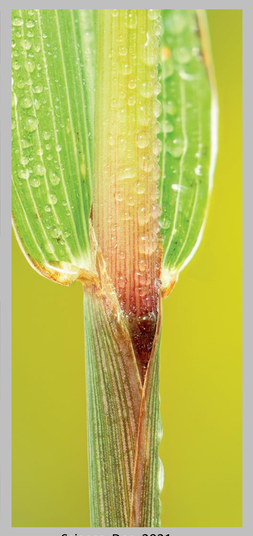


Nelson & Dengler, 1997

Blade



Sheath

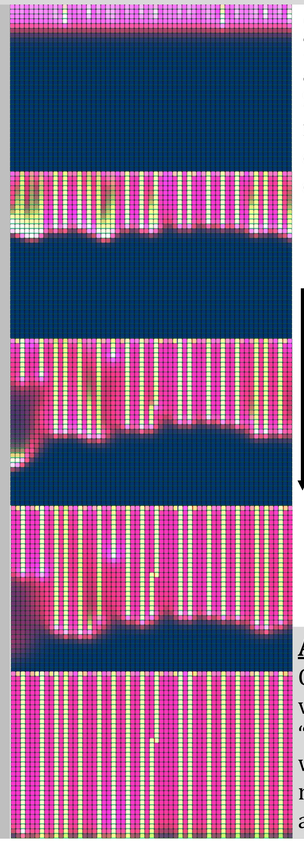


Science, Dec. 2021

Vein Types

Maize leaves have several types of veins appearing in specific configurations and with consistent developmental timing.

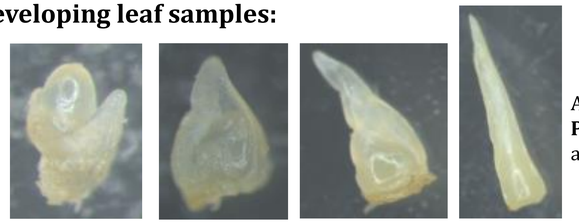
In particular, the "small" veins found only in the leaf blade are implicated in the high vein density required for Kranz anatomy.



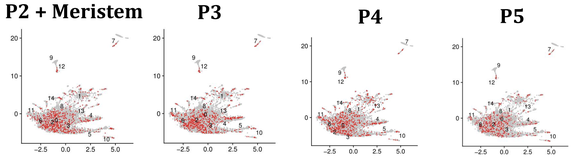
Single-cell Sequencing on a Time Course of Developing Leaves

Single-cell sequencing gives us information about gene expression at the resolution of individual cells. I am using single-nucleus sequencing on developing leaves to identify genes associated with developmental decisions related to vein initiation and specification.

8 developing leaf samples:



And also **P6, P7, P8,** and **Full**

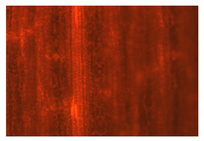


Red dots are nuclei from the above leaf sample

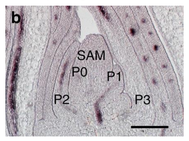
Auxin Dynamics

Computational simulation of vein formation according to the "auxin canalization" hypothesis, where the plant hormone auxin reinforces its own transport like a flowing river.

Sequenced tissue had a fluorescent auxin marker.



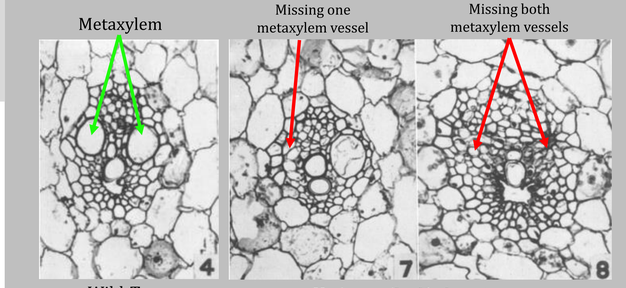
Primordia are named according to age. P2 is younger than P3.



Leiboff et al. 2015

Vascular Mutant Characterization

We are also investigating a cool **single-gene** vascular mutant, *wilted1*.

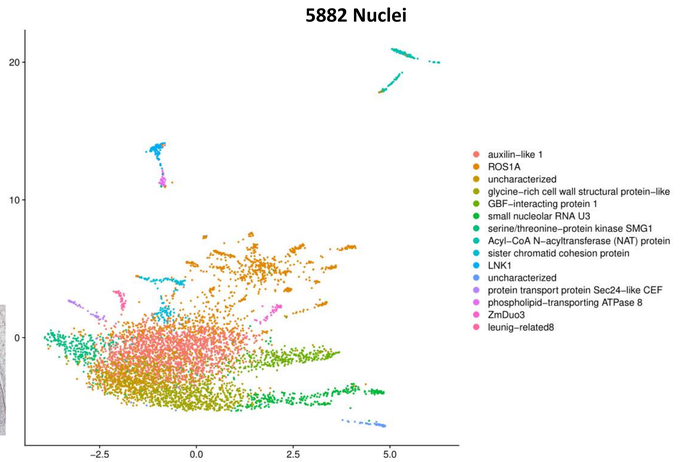


Wild-Type

Various *wilted1* phenotypes

Postlethwait and Nelson, 1957

The UMAP below shows the sequenced nuclei clustered into different groups depending on their gene expression patterns.

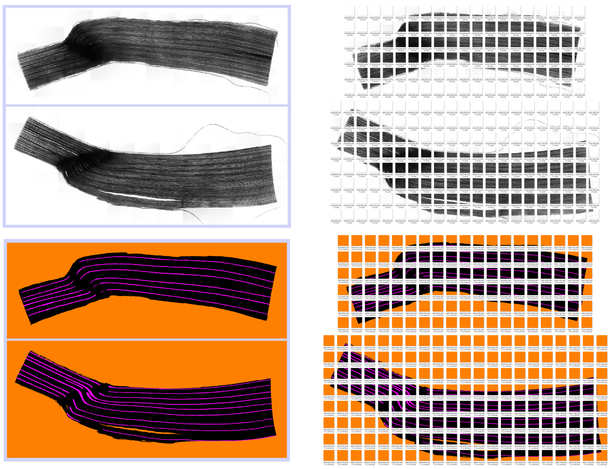


Neural Network for Vein Quantification

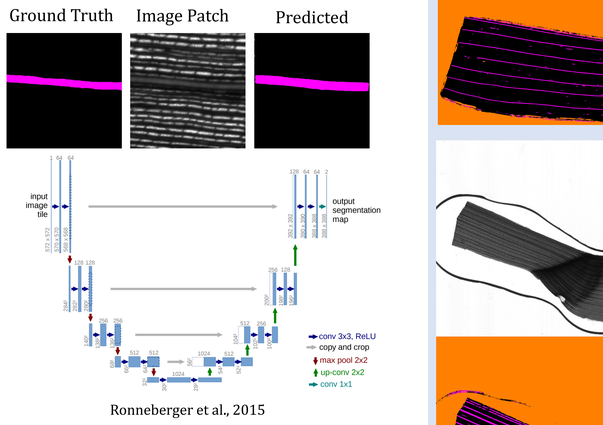
PyTorch

If we can efficiently quantify vascular traits of many genetically diverse lines of maize, we will be able to identify specific genetic differences associated with phenotypic variation.

I am working on a neural network which automatically segments veins of different classes so we will be able to quantify microscopic vascular traits of thousands of leaf samples.



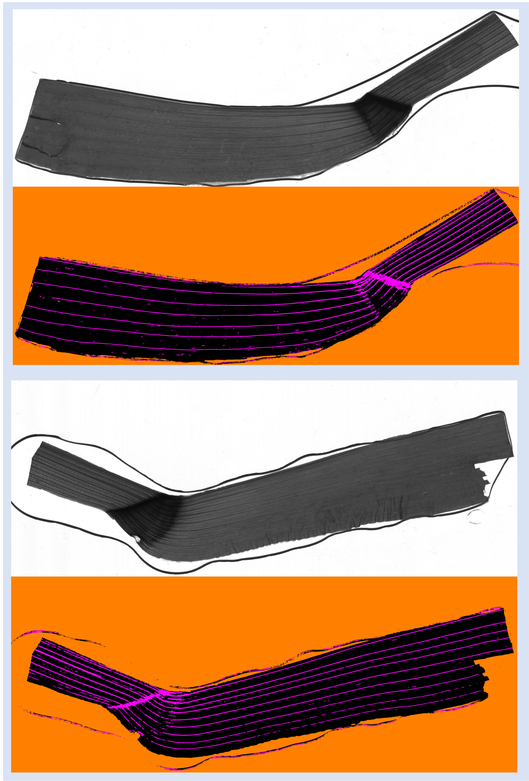
Hand annotated training data is broken into patches and used to train the network.



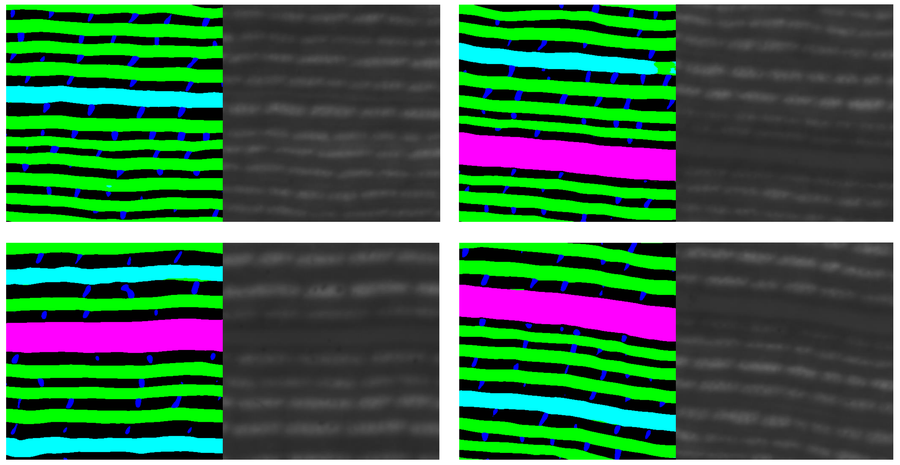
Ronneberger et al., 2015

U-NET is a kind of convolutional neural network (CNN) architecture good for image segmentation.

Inference results on leaves the network has never seen



Preliminary results using all the vein classes are promising. The next step is to generate more training data!



Neural Networks Can Also Count Corn Kernels

Corn ears imaged with a rotating scanner are phenotyped for fluorescent kernels with an object detection neural net.