



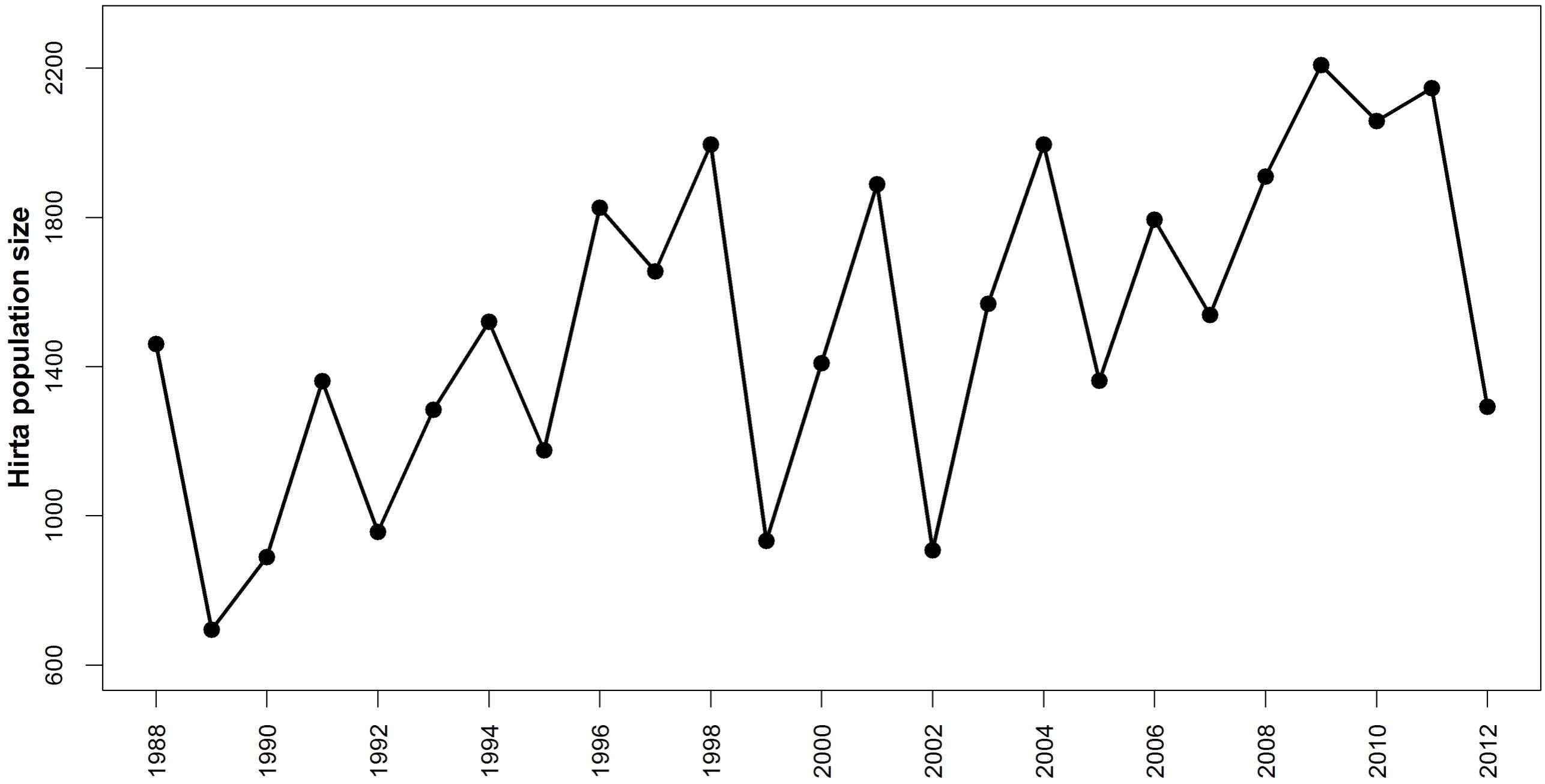
Quantitative Histopathology in the Soay Sheep System

St. Kilda



United
Kingdom

Population Crashes



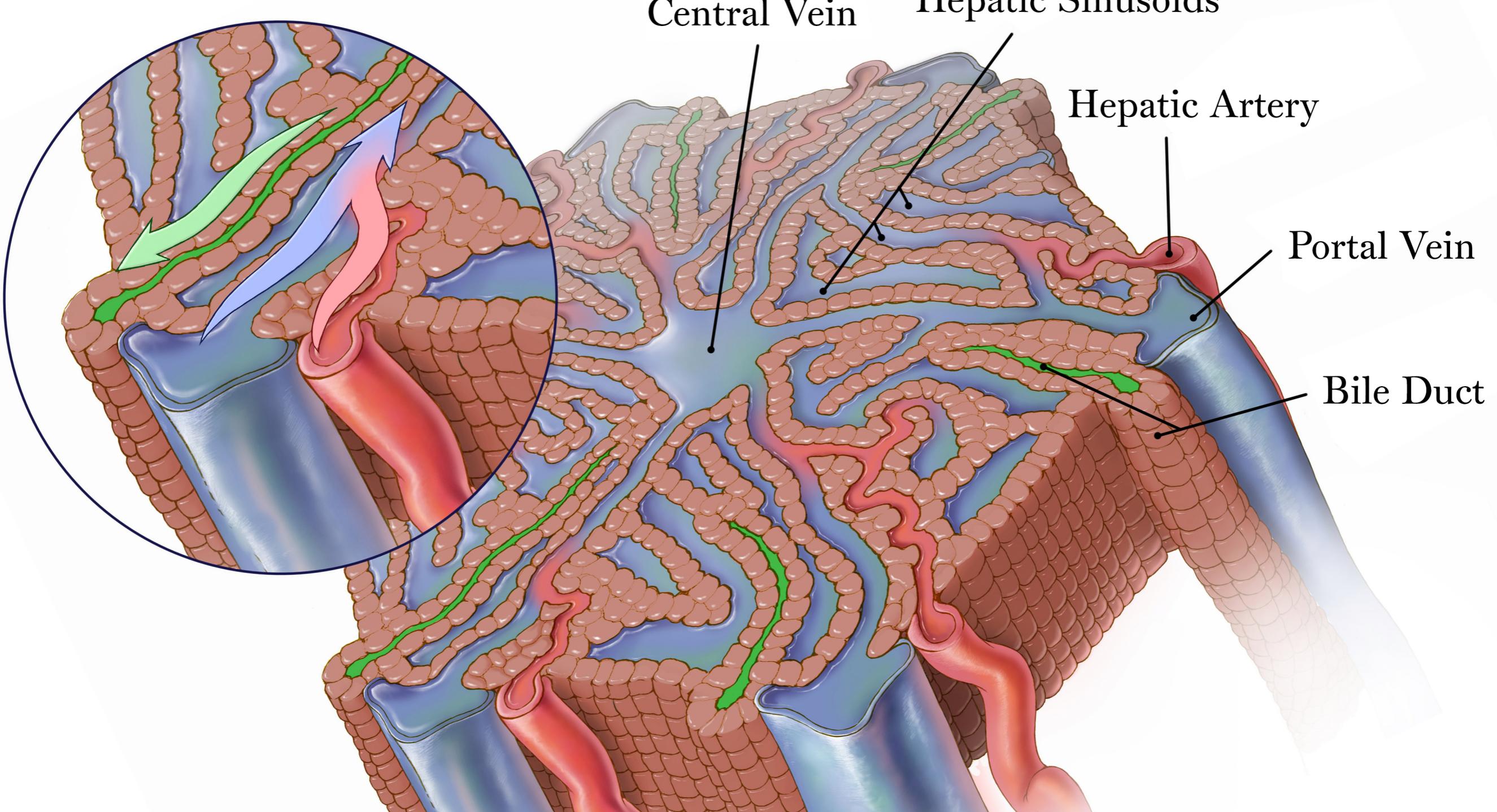
Dead Sheep*

- Emaciated, no fat anywhere
- Oedema
- Friable liver
- Overall not very happy

What does this mean at the cellular level ?

* Not tasty

Liver Structure



Methods

Field

During the winter of 2011 - 2012 :

- Daily monitoring for dead individuals
- 143 samples collected within 24h of death into formaldehyde

Controls :

- Two commercially-raised USA lambs
- One Soay ewe during lambing in 2013

Methods

Lab

Preparation of ~1000 slides :

- Paraffin treatment and sectioning
- Hematoxylin and Eosin staining

Analysis :

- Classical : semiquantitative “scoring”
- Image processing : automated, robust, quantitative information

Methods

Images and Acquisition

Capture :

- Optical microscope into DSLR
- Wide-field : 5322 images; narrow-field : 13870 images
- One poor, unfortunate postdoc

Specifications :

- 18 MPix, 3 channels, 14 bits per channel, RAW

Image Processing

Preprocessing

Global :

- Contrast and sharpness enhancement
- Vignetting reduction
- Colour homogenisation

Quality Control :

- Poor postdoc : wide-field 5322 to 4434 images (17% dropped)

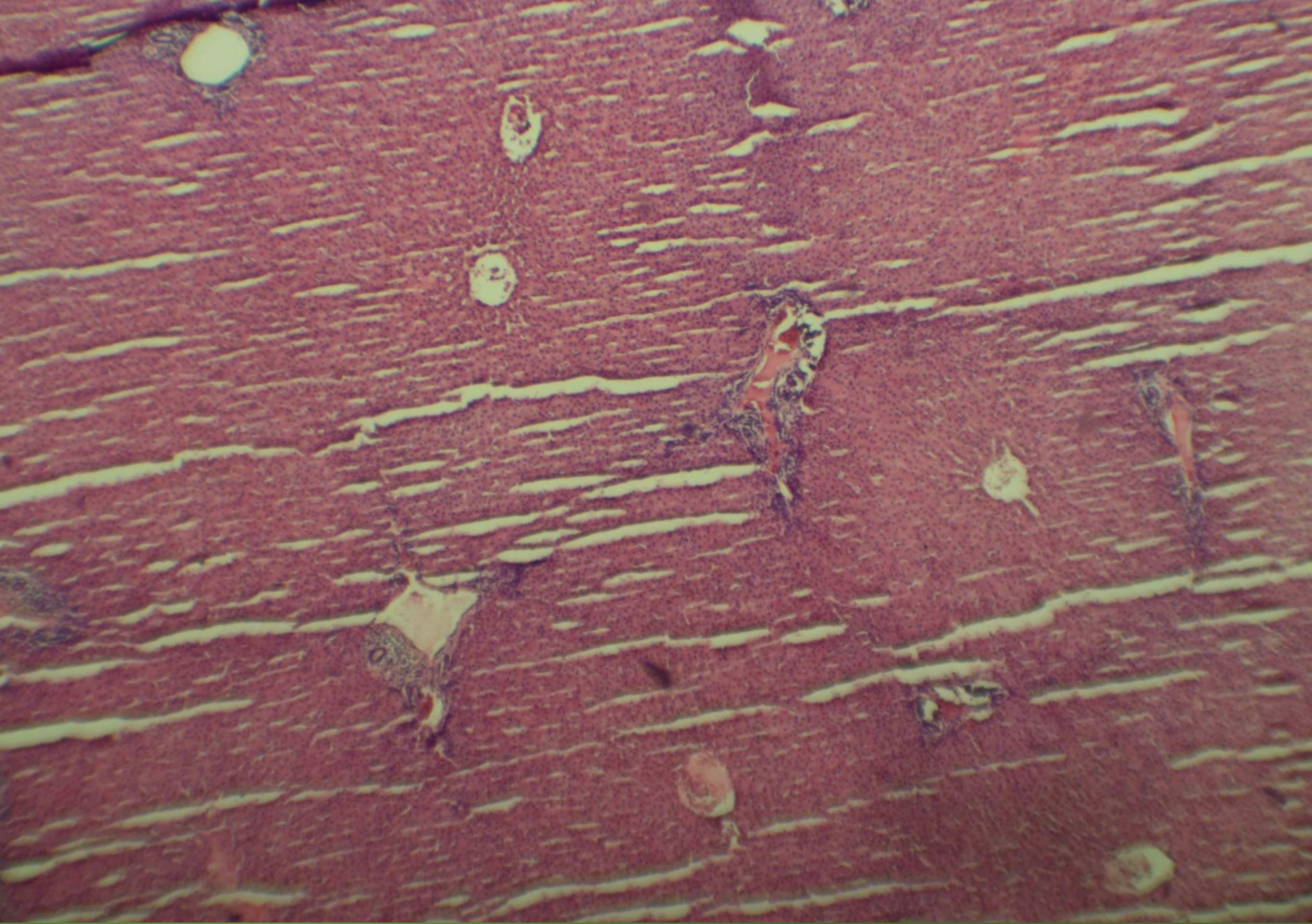


Image Processing

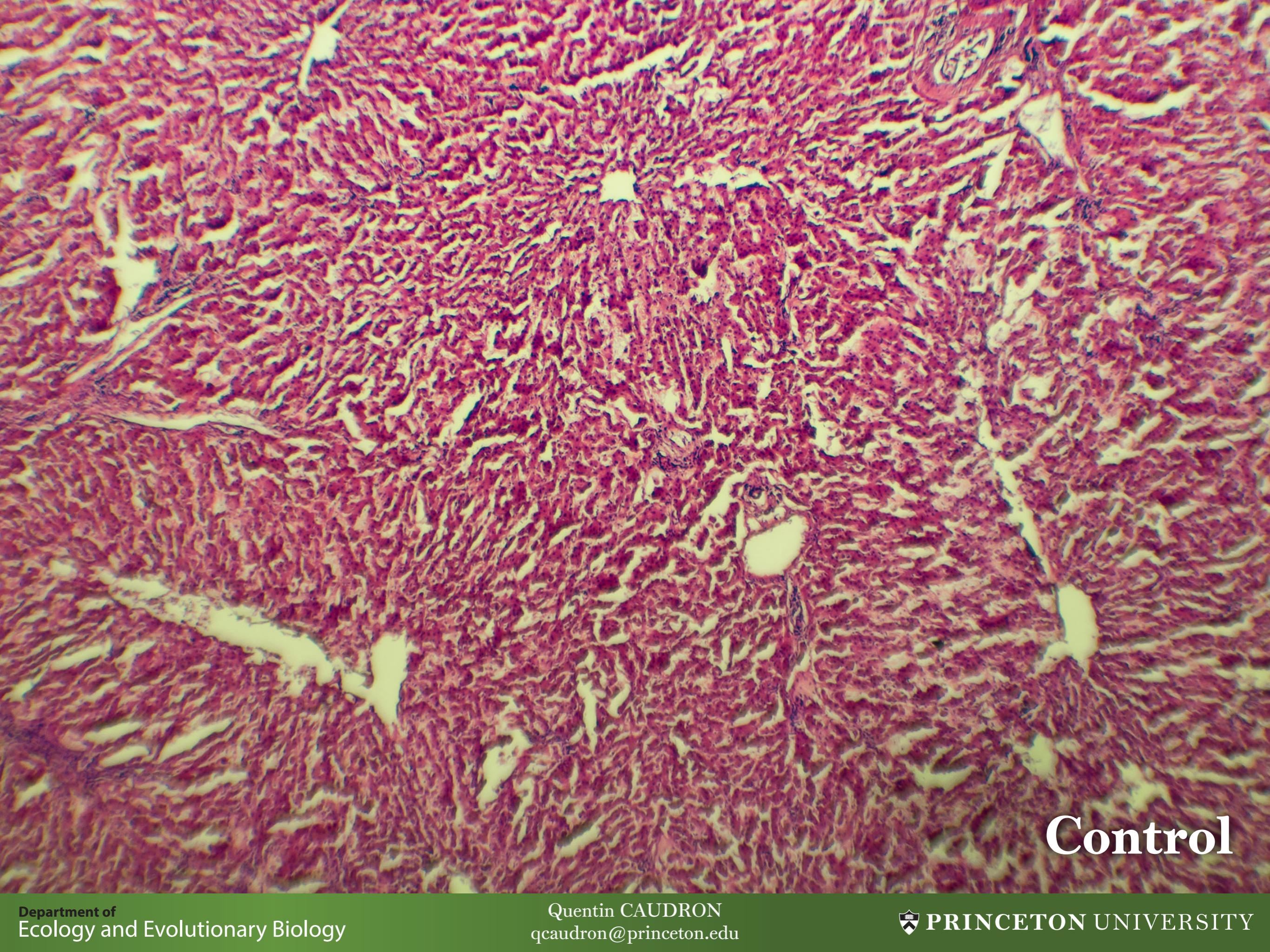
Processing

Global :

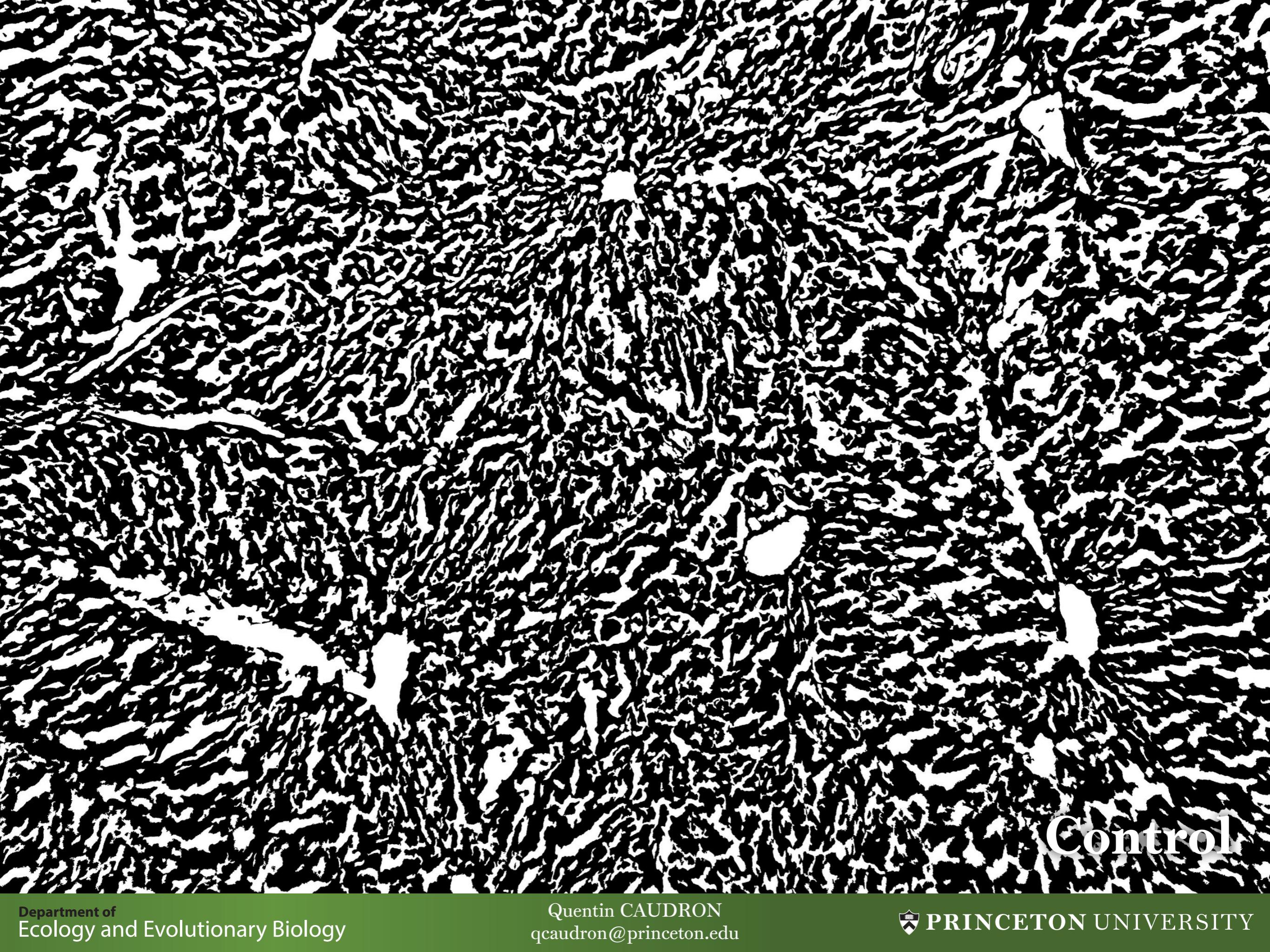
- Sigmoid transform
- Transform to luminosity image

Local :

- Adaptive thresholding (300 pixels)
- Remove noise

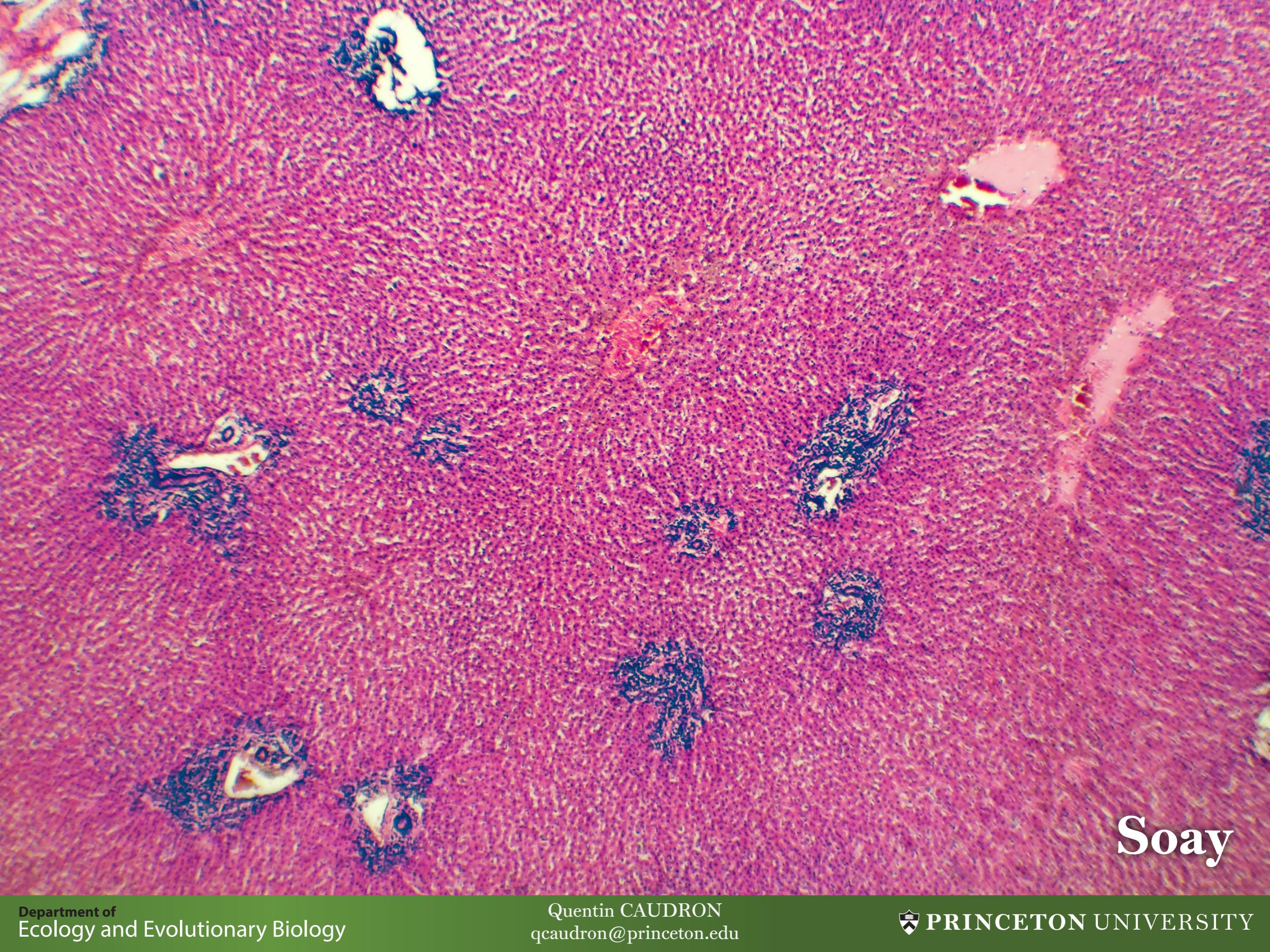


Control

The background of the slide features a dense, abstract pattern of black and white shapes, resembling a type of camouflage or noise. It consists of numerous irregular, jagged, and wavy patterns of varying sizes.

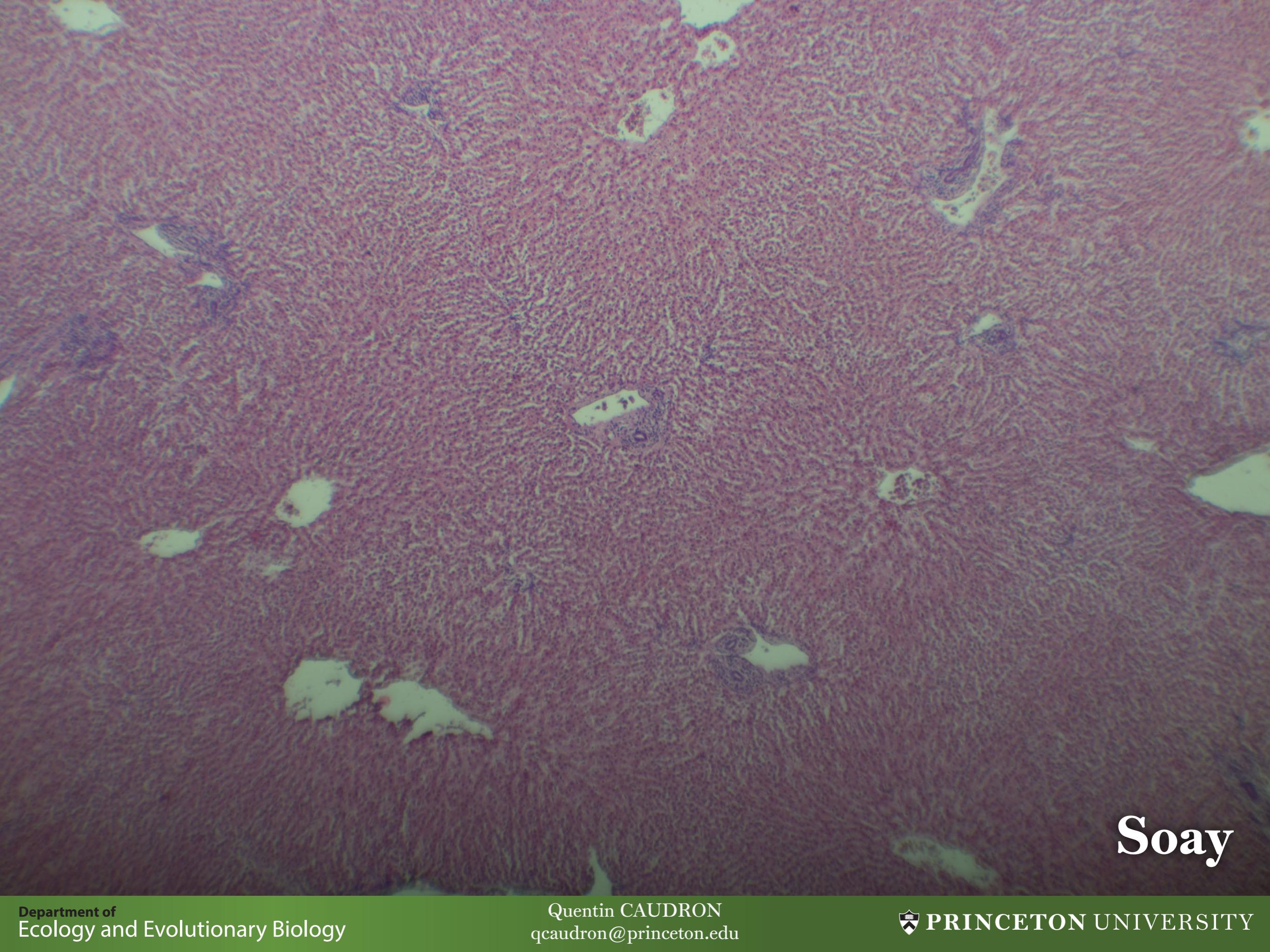
Control



Soay

A black and white photograph of a Soay sheep, showing its dark, wavy coat and curved horns. The sheep is positioned in the lower-left corner of the frame.

Soay



Soay



Soay

Feature Engineering

Features

Lacunarity

Clustering of hepatic sinusoids / capillaries

Entropy

Complexity, repeatability, “patternedness”

Characteristic Scale

Breadth-wise scale distribution of capillaries

Directionality

Net preference for a particular direction



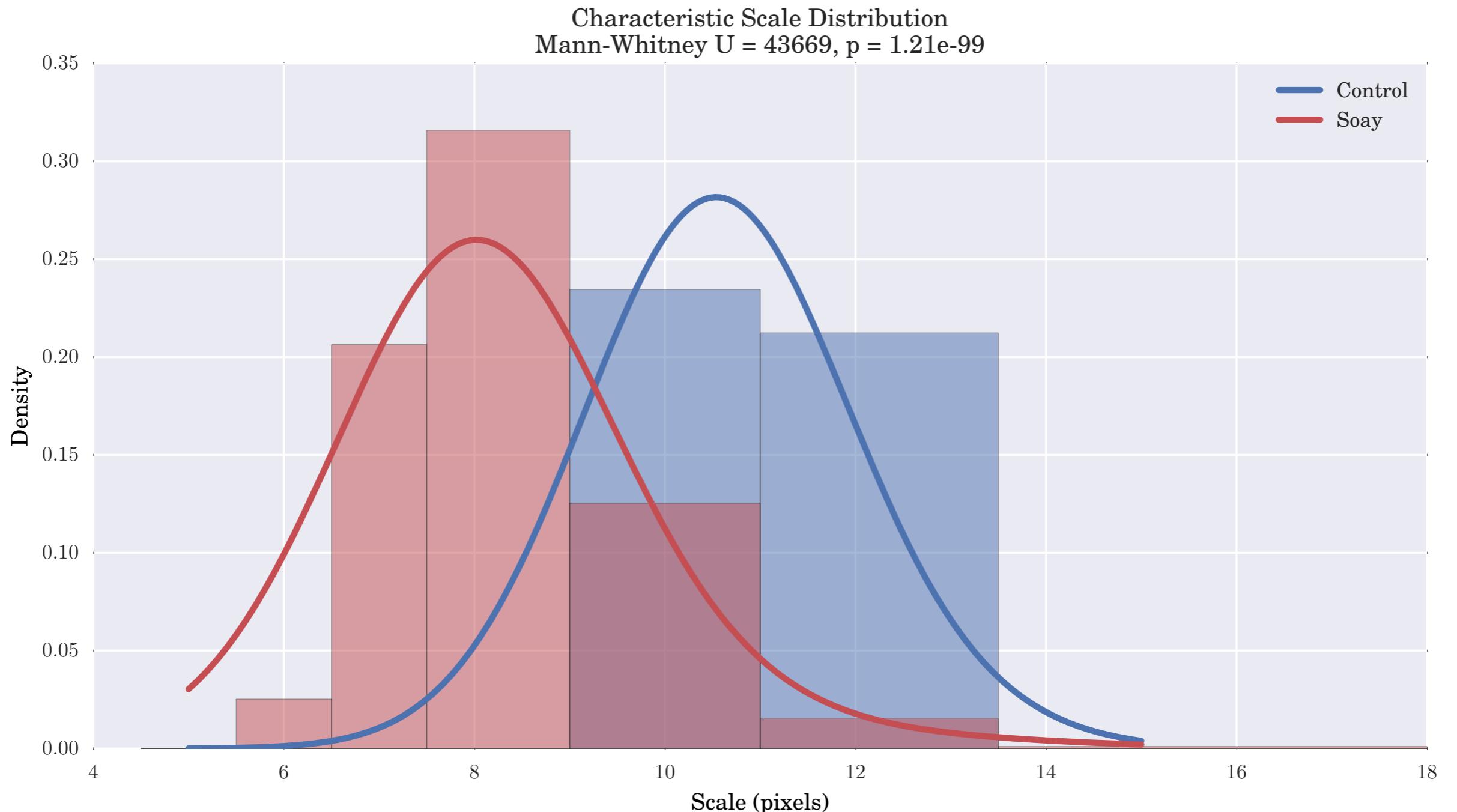
Control

A histological slide showing a tissue sample from a Soay sheep. The tissue is stained with hematoxylin, giving it a deep purple hue. It features a dense, organized structure of small, rounded cells, likely muscle tissue. Several larger, irregularly shaped white areas are visible, which are characteristic of mineralized structures called ossicles or myosites. These white areas contain darker, more granular material, possibly calcium deposits.

Soay

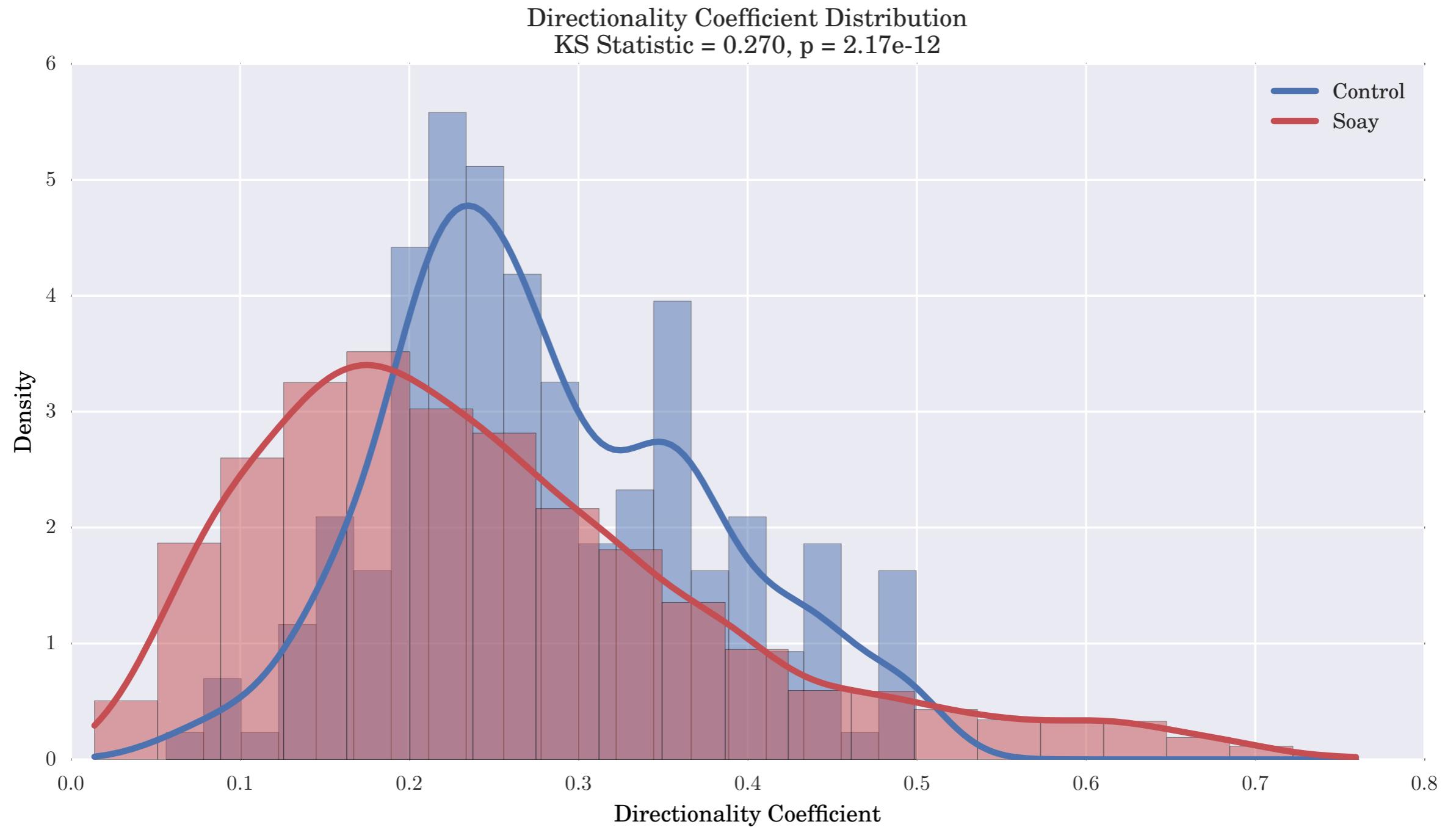
Results

Scale



Results

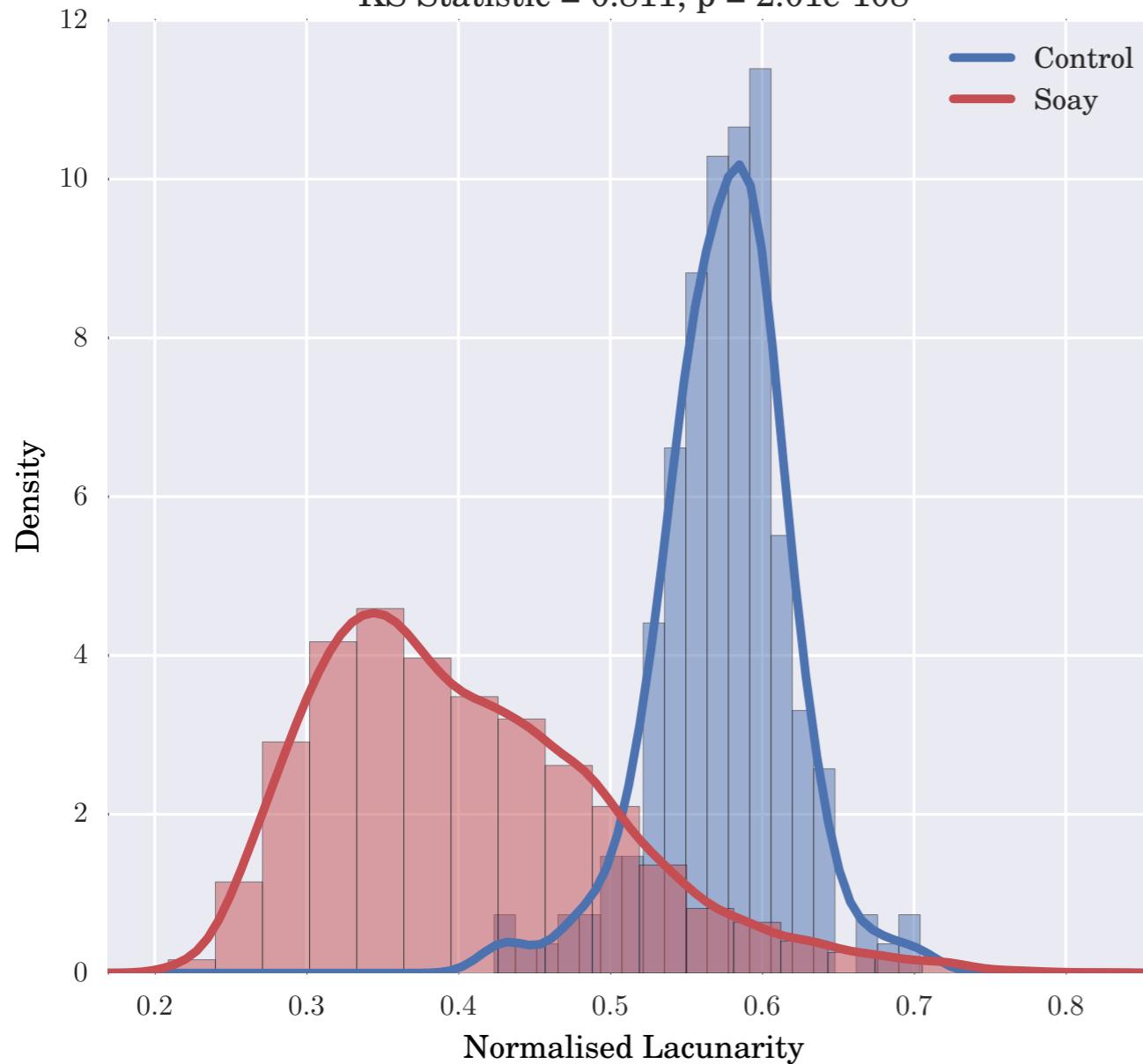
Directionality



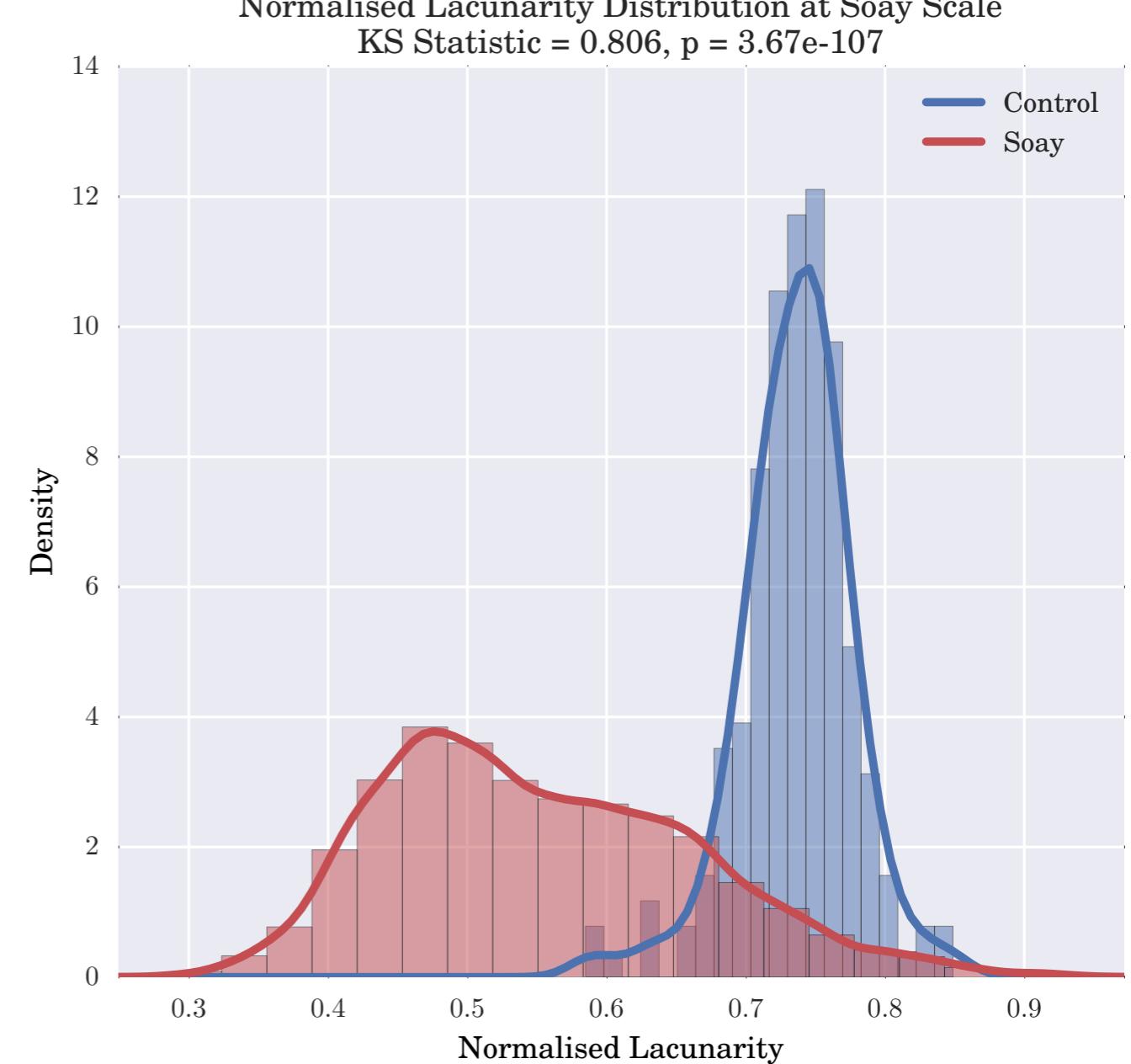
Results

Lacunarity

Normalised Lacunarity Distribution at Control Scale
KS Statistic = 0.811, p = 2.01e-108



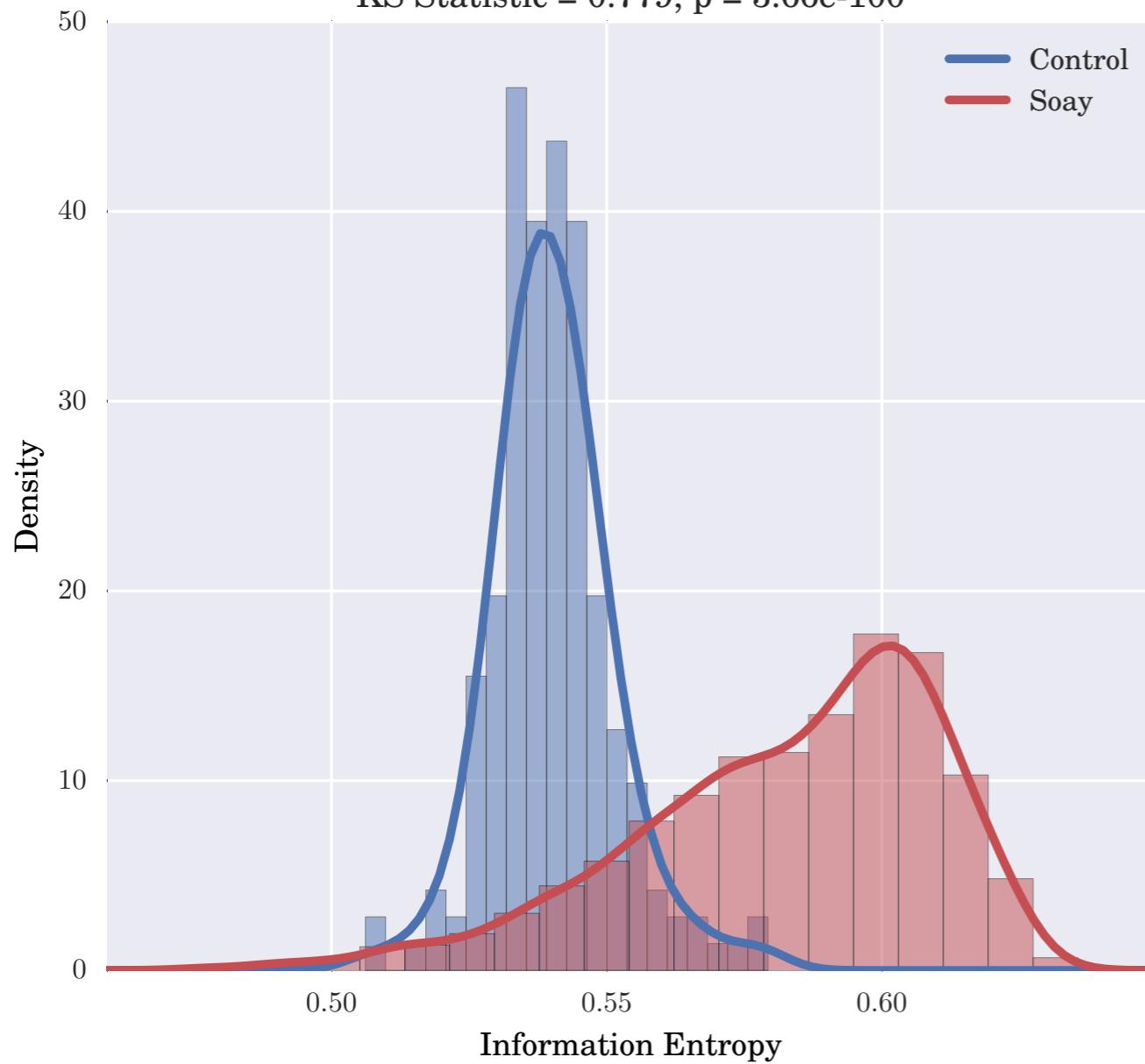
Normalised Lacunarity Distribution at Soay Scale
KS Statistic = 0.806, p = 3.67e-107



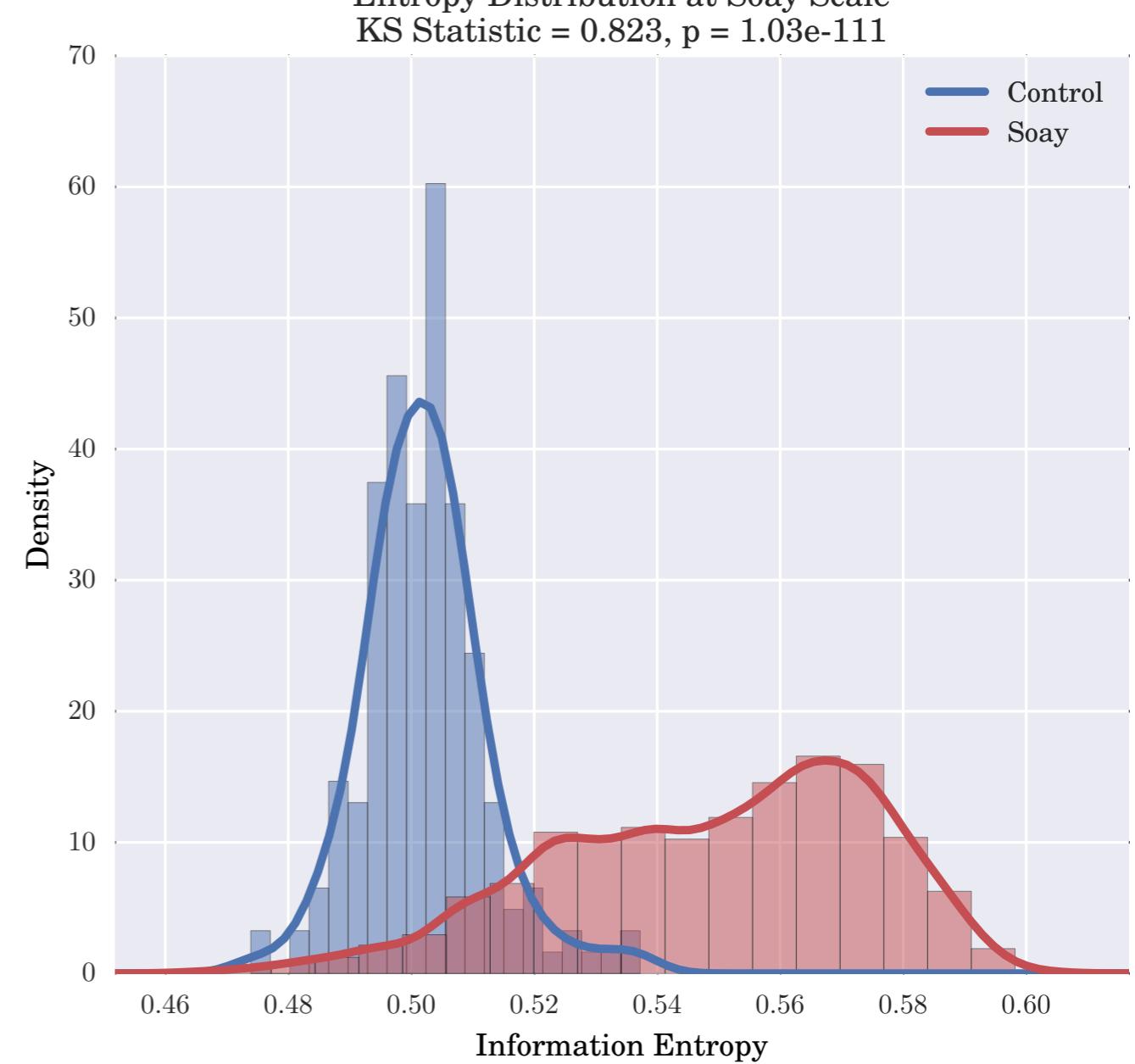
Results

Directionality

Entropy Distribution at Control Scale
KS Statistic = 0.779, p = 3.66e-100



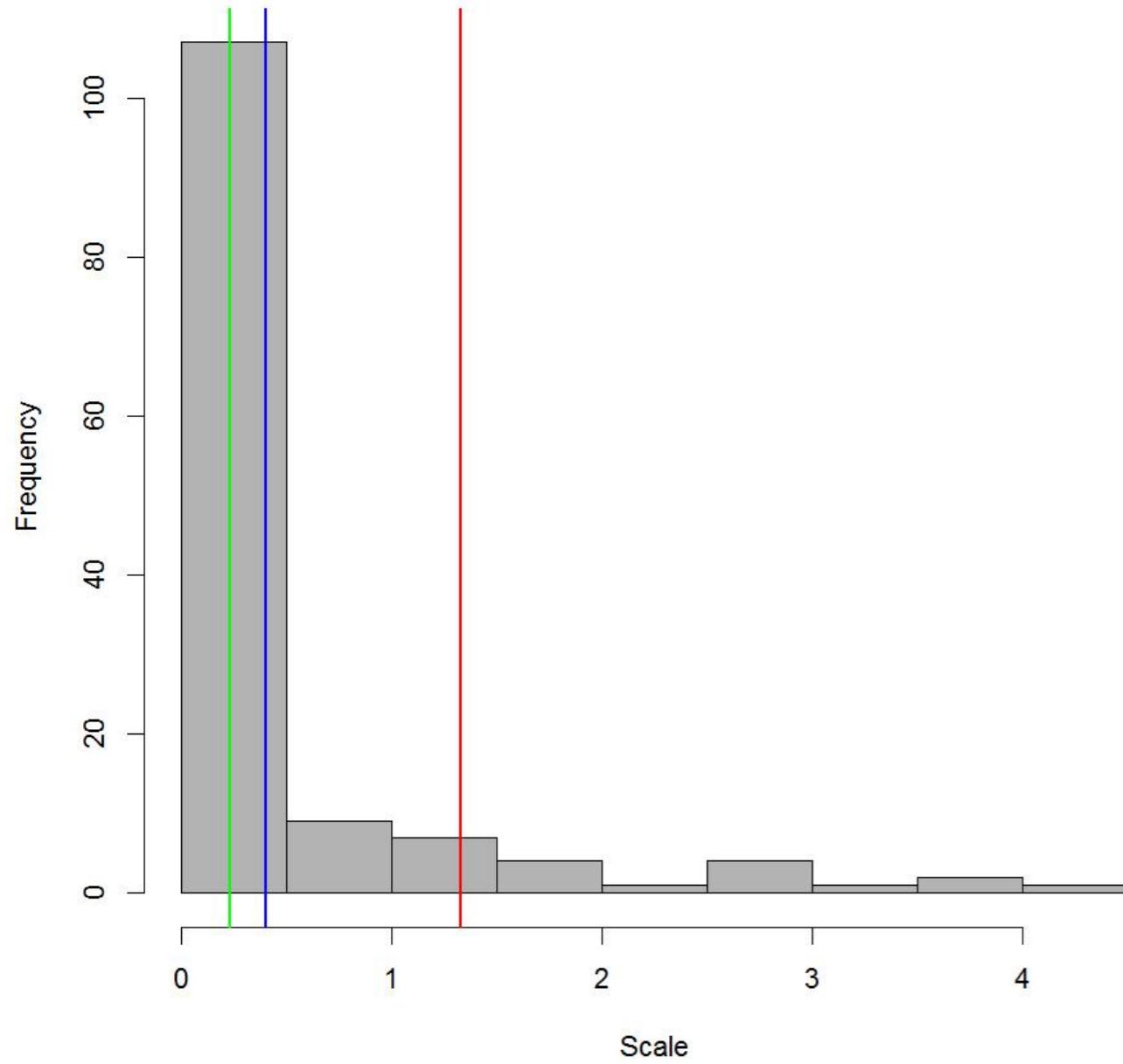
Entropy Distribution at Soay Scale
KS Statistic = 0.823, p = 1.03e-111



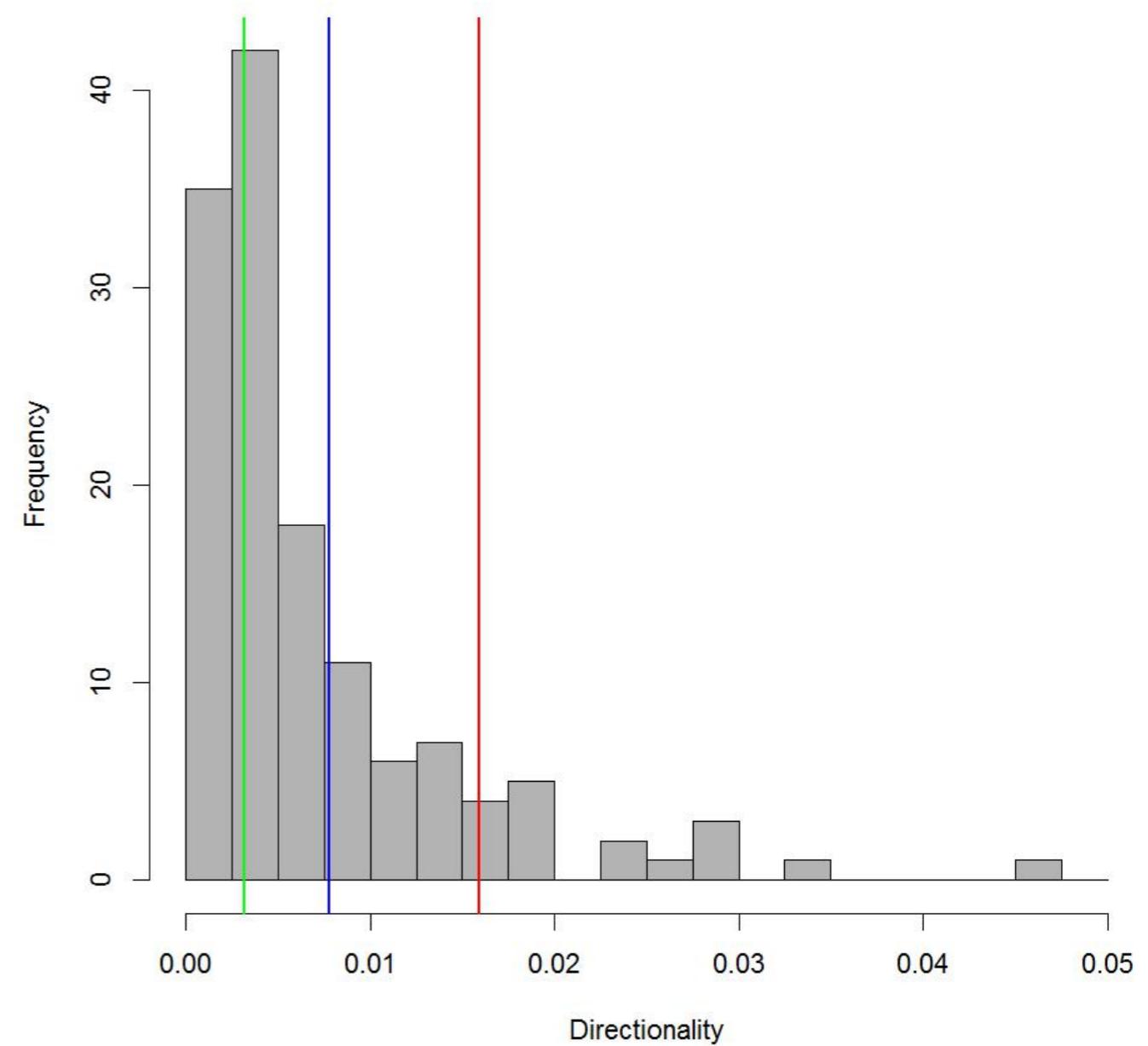
Analysis

Scale and Directionality

Intraindividual variance at characteristic scale



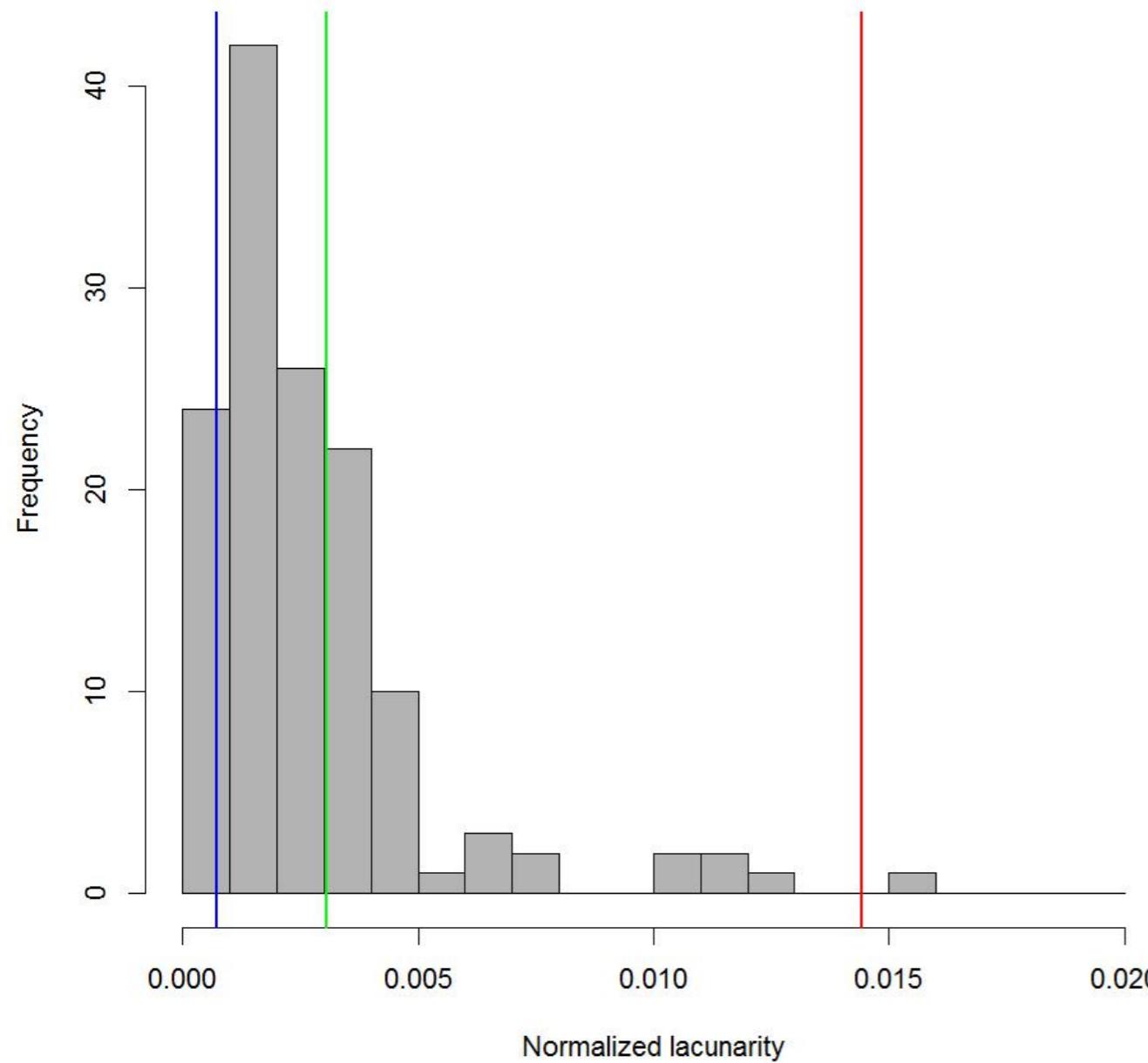
Intraindividual variance at characteristic scale



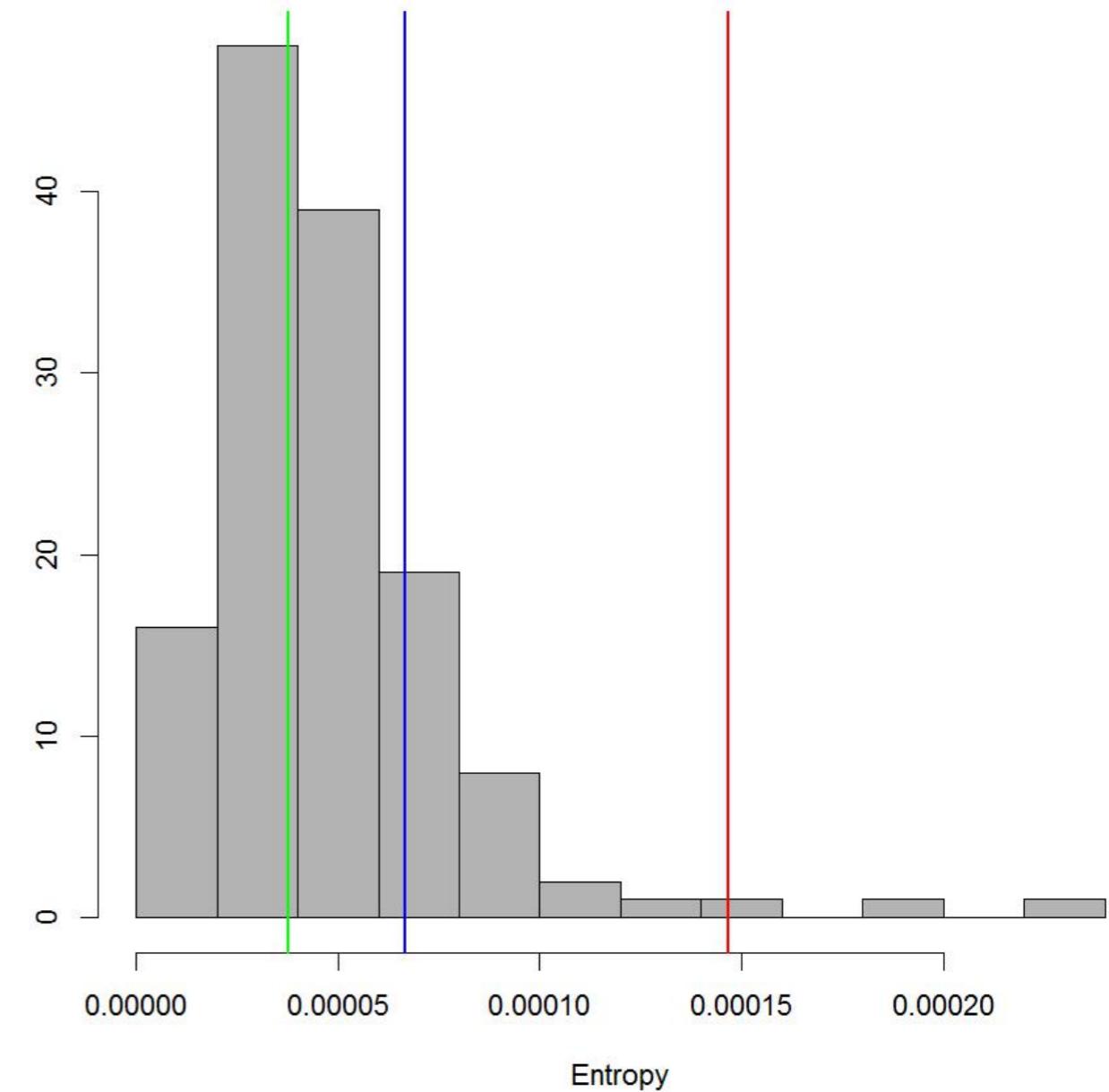
Analysis

Lacunarity and Entropy

Intraindividual variance at characteristic scale

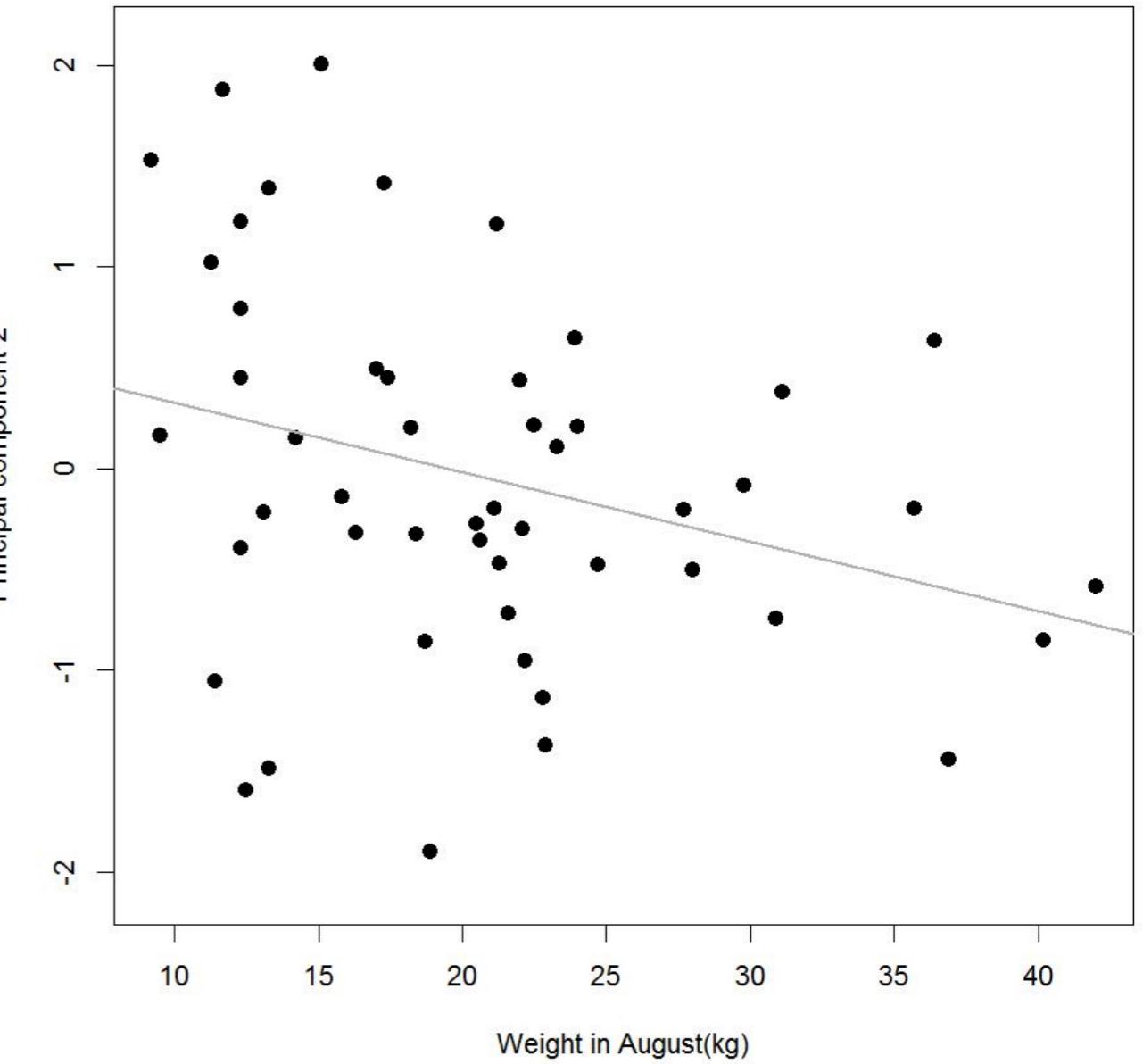
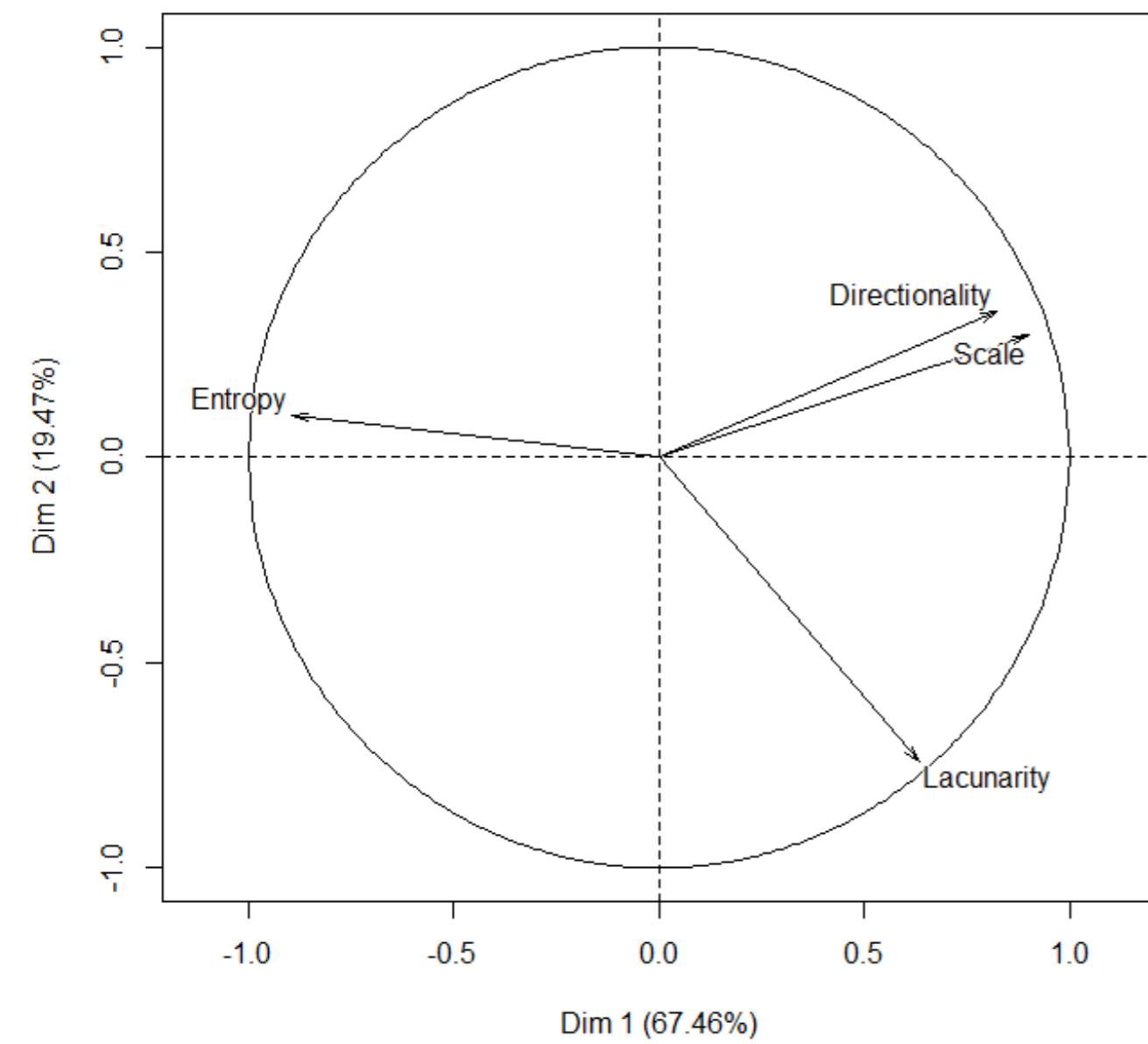


Intraindividual variance at characteristic scale



Analysis PCA

Variables factor map (PCA)

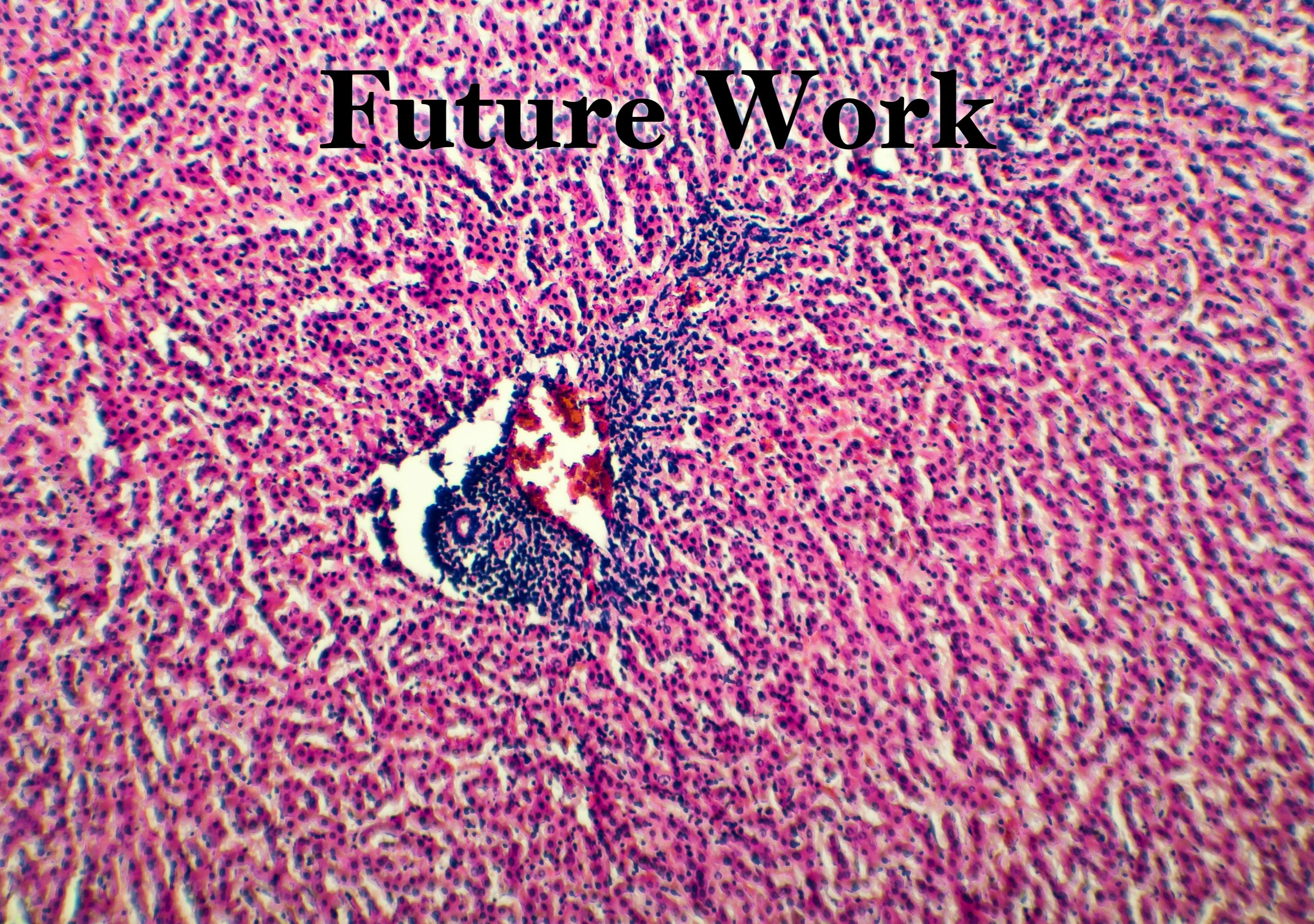


The Big Question

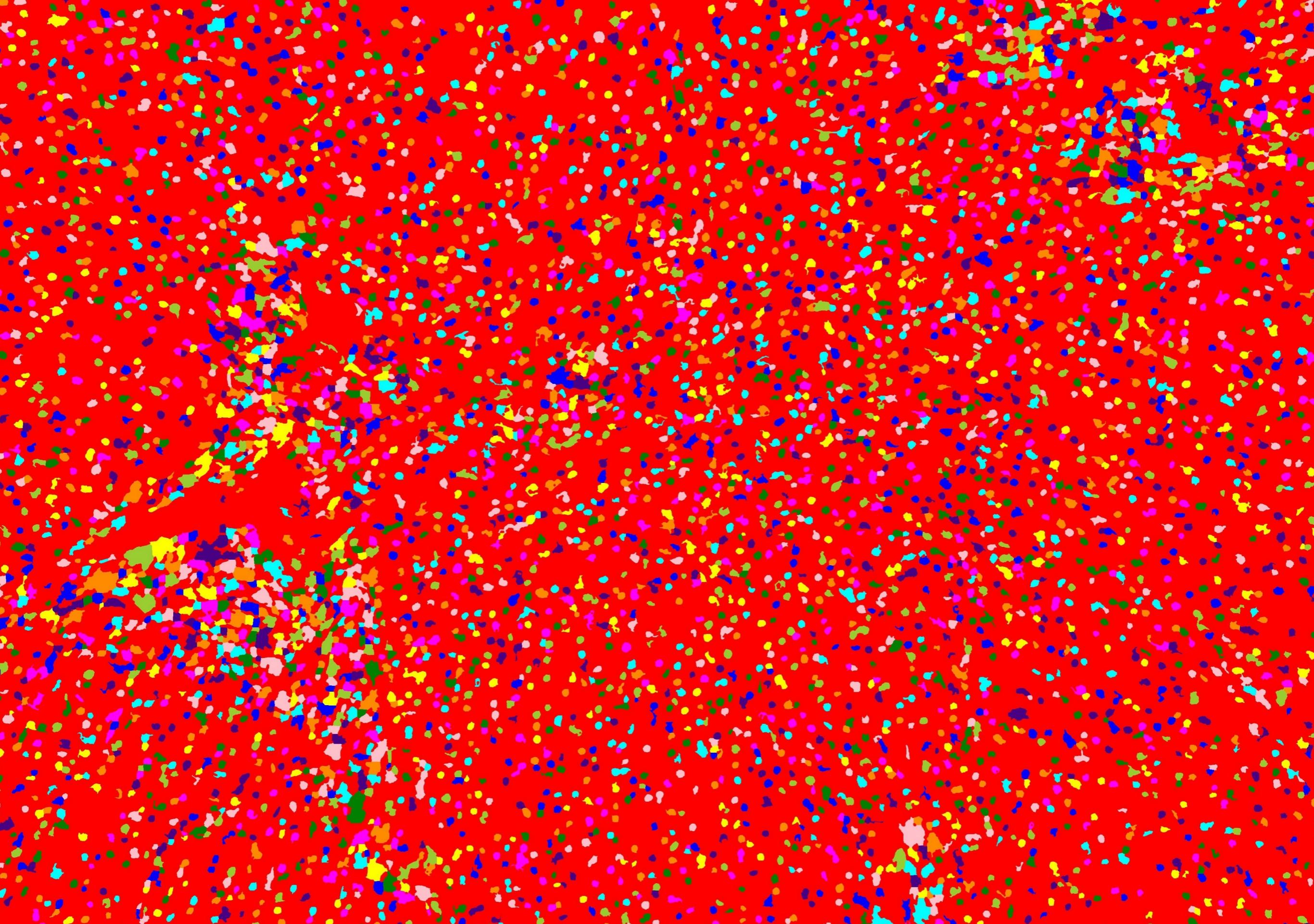
Can we use histological information with phenotypic markers ?

- **Nutritional information** : are protein levels prior to a crash predictive of liver degeneration ? Could a positive correlation imply a death due to nematodes ?
- **Antibodies** : are levels of autoreactive antibodies associated with development of hepatic inflammation during crashes ?

Future Work







Collaborators



PRINCETON
UNIVERSITY

Romain Garnier
Andrea Graham



