Biological Image Analysis using the ImageJ/Fiji Software Ecosystem

ImageXD - March 30, 2017

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Some presentation material adapted from
Curtis Rueden's imagej-presentations

WHAT IS IMAGEJ?

FIJI?

IMAGEJ2?

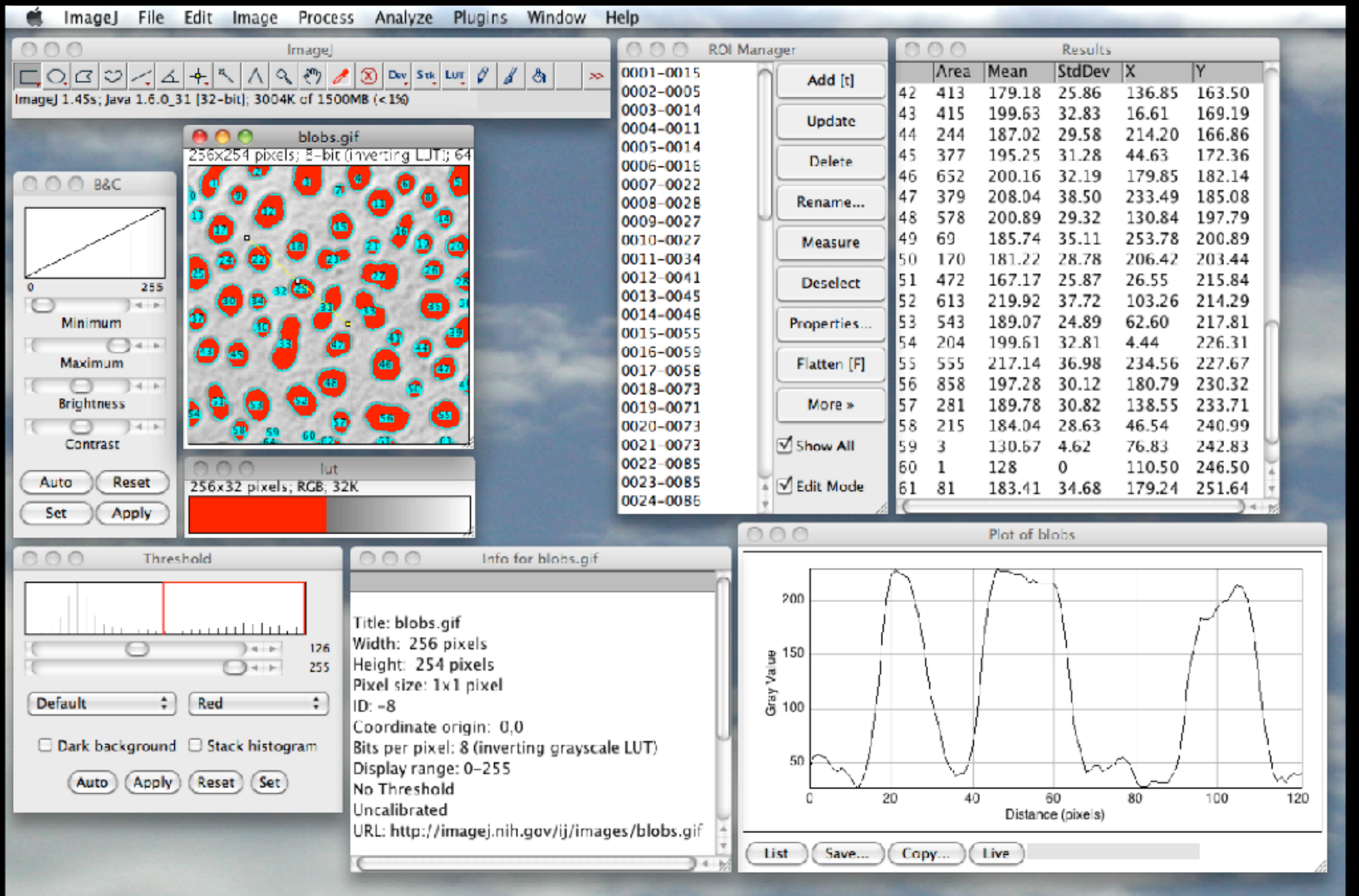
IMAGEJ1?

IMGLIB2?

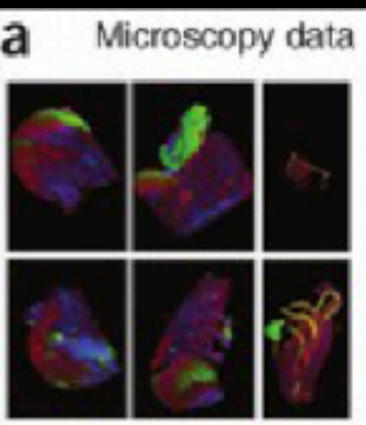
SCIJAVA?

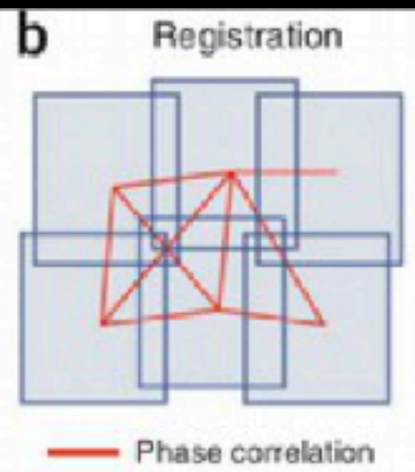
SCIFIO?

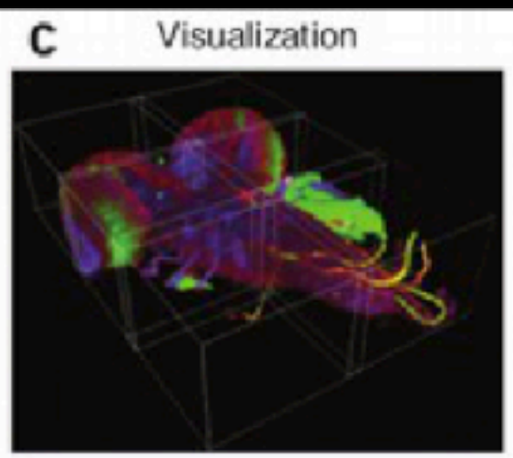
An Application

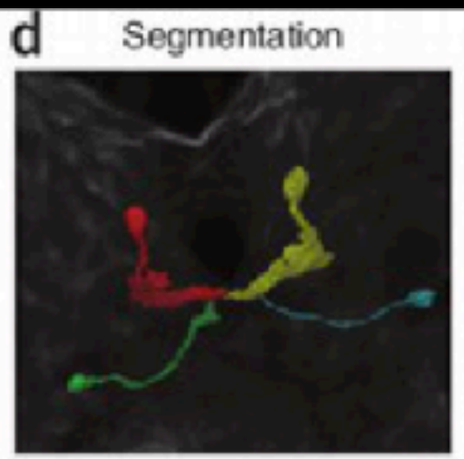


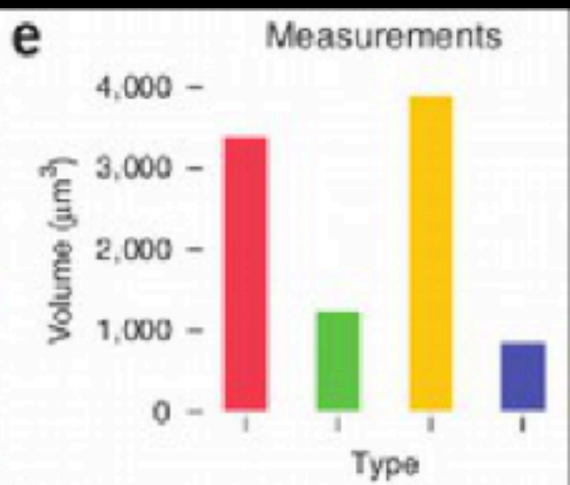
A Tool for Image Science

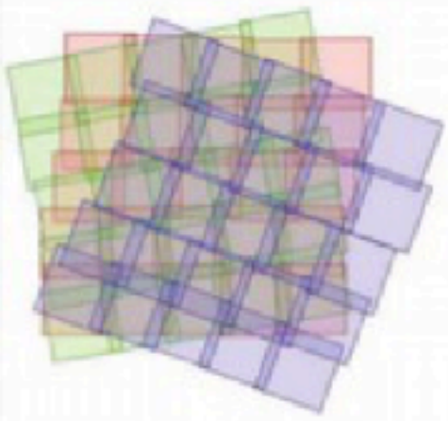


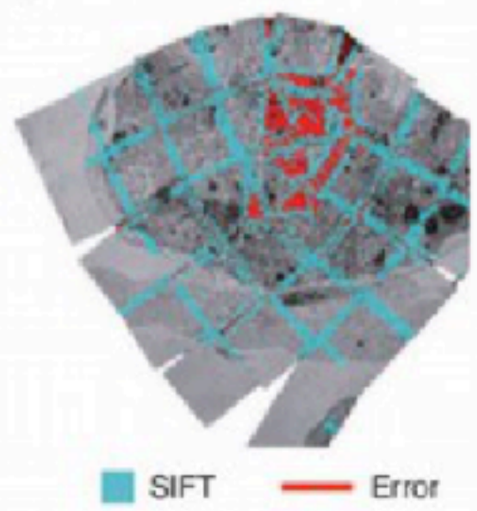


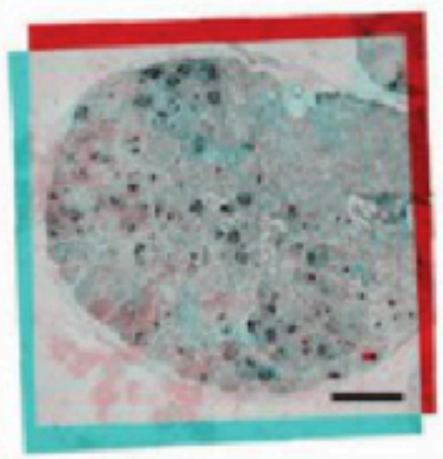


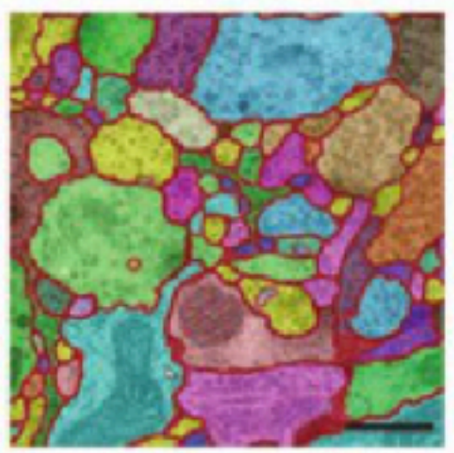


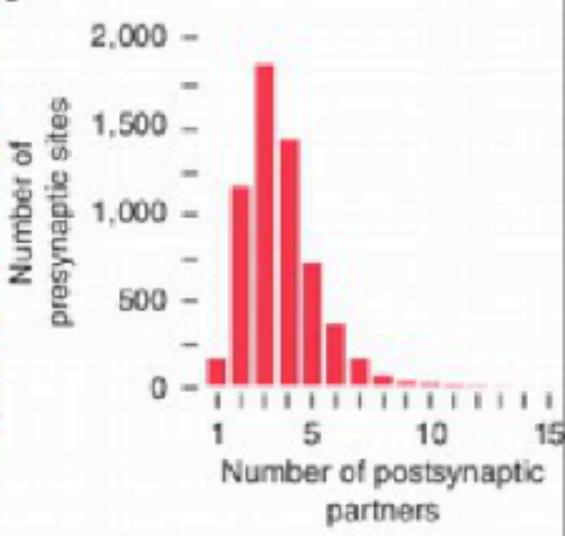


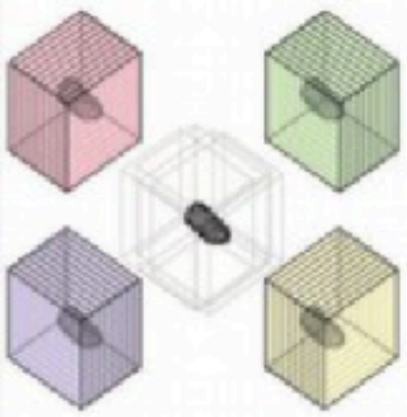


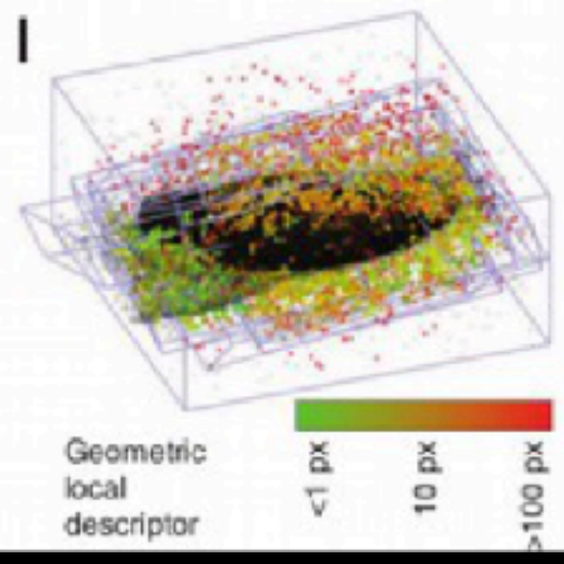


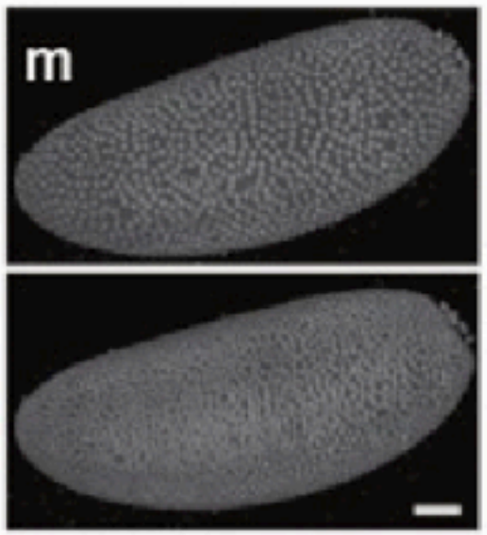


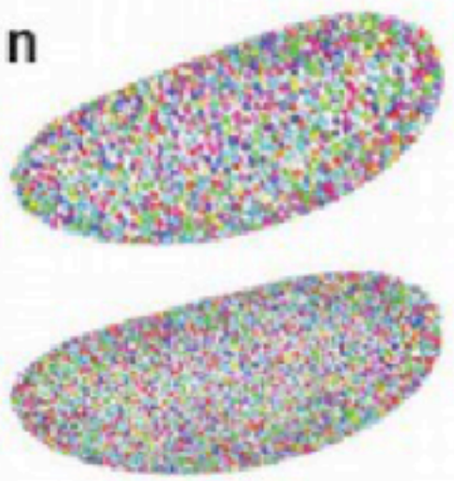


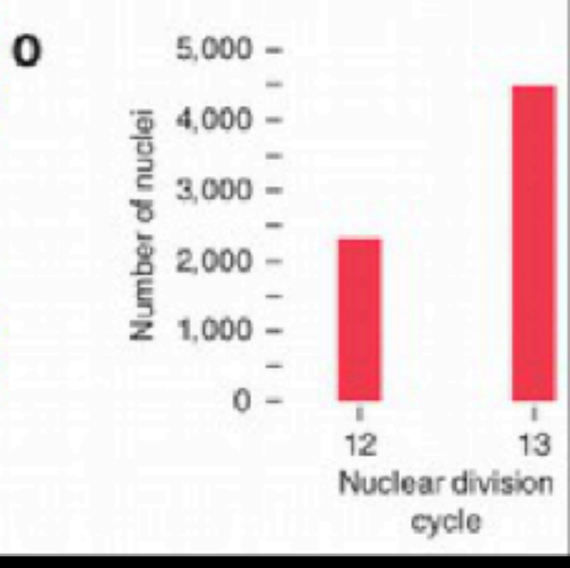












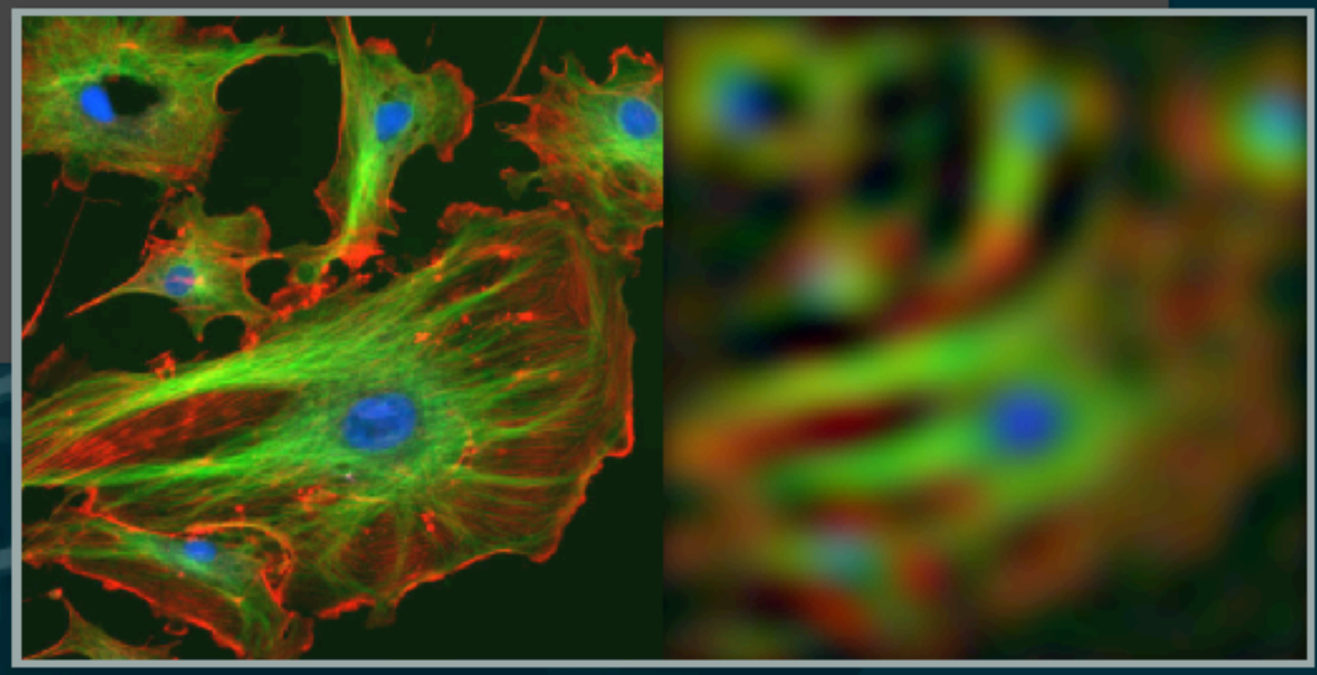
A Reusable Library

```
// Create a new ImageJ gateway with all available services.
ij = new ImageJ()

// Load a dataset from somewhere.
dataset = ij.io().open(imageSource)

// Filter the image.
fft = ij.op().fft(dataset)
lowpass(fft, 10)
result = ij.op().ifft(fft)

// Display the result.
ij.ui().show(result)
```



https://imagej.github.io/tutorials

ImageJ Modules: the new IJ macro

```groovy
// @OpService ops
// @ImgPlus inputData
// @Integer center
// @OUTPUT ImgPlus(label="Filtered") filtered
// @OUTPUT ImgPlus(label="Convolved") result

// This script takes an input image, applies a gaussian filter
// to it, and then performs convolution with a custom kernel.

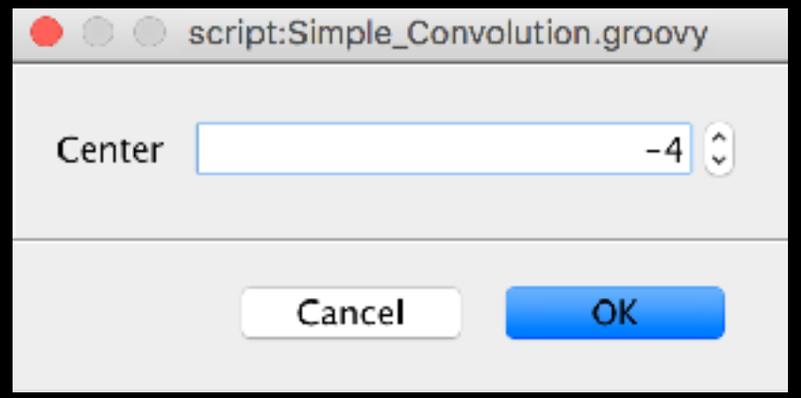
// Convert the input image
img32 = ops.convert().int32(inputData)

// Apply the gaussian filter
filtered=ops.filter().gauss(img32, [4.0,4.0])

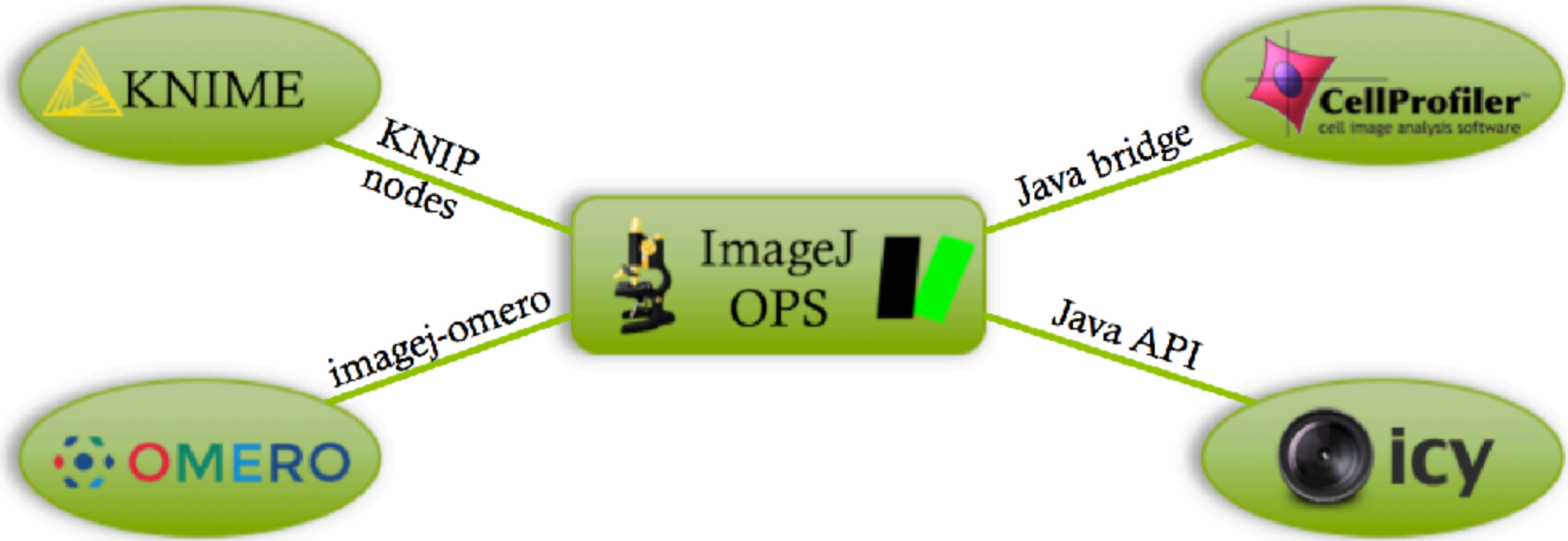
// Create the kernel
kernel=ops.create().kernel([[0,1,0],[1,center,1],[0,1,0]])

// Perform convolution
result=ops.filter().convolve(filtered, kernel)

```

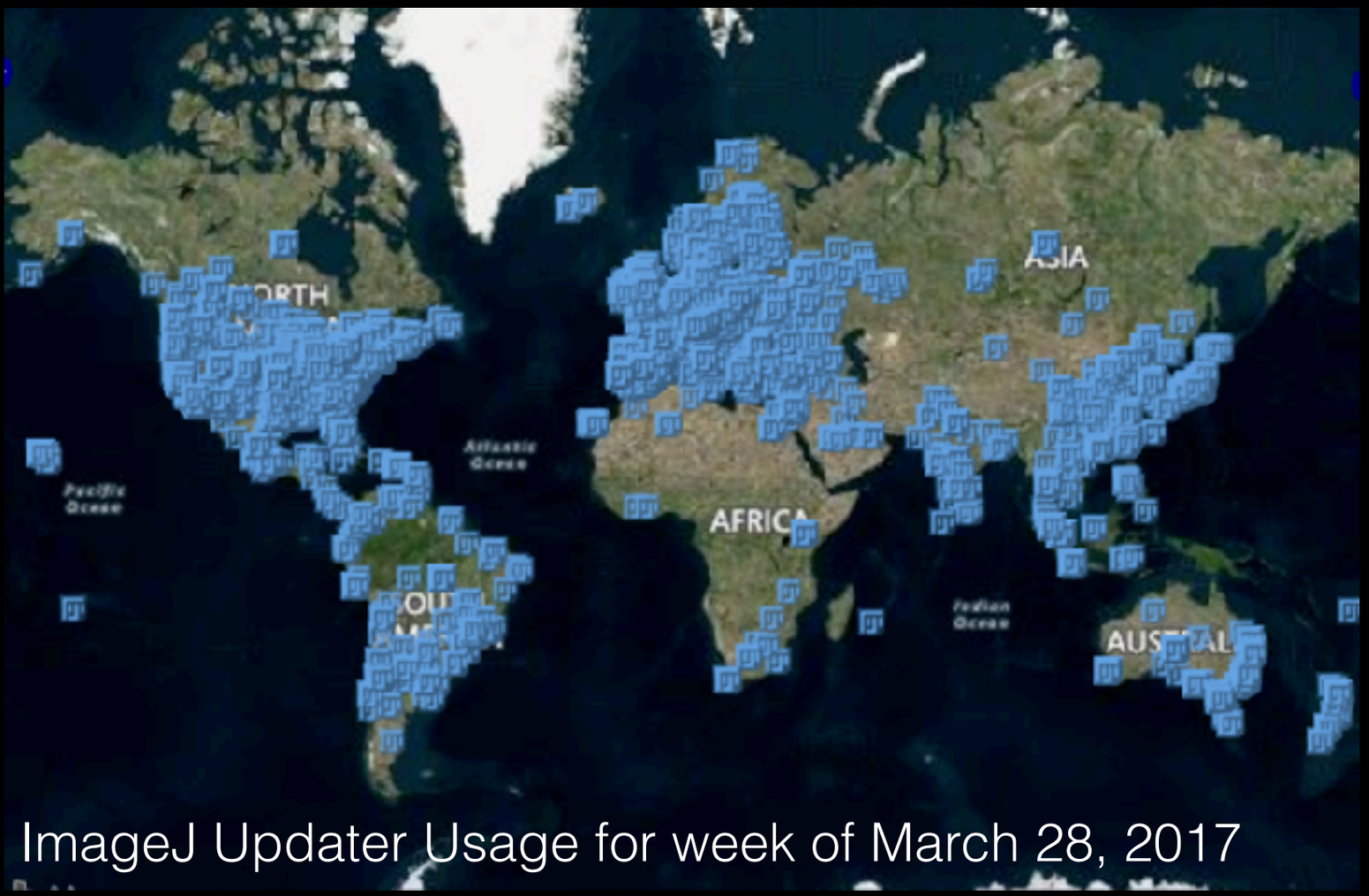


A Shared Framework for Image Processing



"Write once, run anywhere" image processing

A Community



ImageJ Updater Usage for week of March 28, 2017



Principal investigators

- Kevin Eliceiri[2] (ImageJ/Fiji, OME)
- Pavel Tomancak[3] (ImageJ/Fiji)
- Anne Carpenter[4] (CellProfiler, ImageJ)
- Michael Berthold[9] (KNIME)
- Jason Swedlow[10,11] (OME)

ImageJ

- Wayne Rasband[1] (lead, ImageJ 1.x)
- Curtis Rueden[2] (lead, ImageJ2)
- Christian Dietz[9]
- Brian Northan[15]
- Mark Hiner[2] (Sep 2010-Jun 2016)
- Lee Kamentsky[4] (Jan 2010-Apr 2016)
- Johannes Schindelin[2] (Sep 2011-Nov 2014)
- Aivar Grislis[2] (Jan 2010-Dec 2013)
- Barry DeZonia[2] (Jan 2010-Nov 2013)
- Grant Harris[3] (Nov 2009-Jan 2012)
- Adam Fraser[3] (Nov 2009-Aug 2011)
- Rick Lentz[2] (Nov 2009-Feb 2011)
- See also ImageJ forum heroes

ImgLib2

- Tobias Pietzsch[2] (lead)
- Stephan Preibisch[3]
- Stephan Saalfeld[3,12]

Fiji

- Curtis Rueden[2] (lead)
- Jean-Yves Tinevez[8]
- Ignacio Arganda-Carreras[14]
- Stephan Preibisch[3]
- Stephan Saalfeld[3,12]
- Tobias Pietzsch[2]
- Jan Eglinger
- Tiago Ferreira
- Daniel James White
- Gabriel Landini
- Kyle Harrington[15]
- Thorsten Wagner[16]
- Mark Hiner[2] (former)
- Albert Cardona[6,12] (founder)
- Johannes Schindelin[2] (founder)
- See also graph of Fiji contributors

BigDataViewer

- Tobias Pietzsch[2] (lead)
- Stephan Preibisch[3]

TrakEM2

- Albert Cardona[6,12] (lead)
- Stephan Saalfeld[3,12]

SCIFIO

- Curtis Rueden[2] (lead)
- Mark Hiner[2] (founder)

CellProfiler

- Allen Goodman[4] (lead)
- Lee Kamentsky[4] (former)

KNIME Image Processing

- Christian Dietz[9] (lead)
- Martin Horn[9]
- Tim-Oliver Buchholz[9]
- Jonathan Hale[9]
- Gabriel Einsdorf[9]
- Andreas Burger[9]
- Daniel Seebacher[9] (former)
- Michael Zinsmaier[9] (former)

OME

- Josh Moore[11,13] (co lead)
- Jean-Marie Burel[13] (co-lead)
- Chris Allan[11] (co lead)
- See also OME Teams

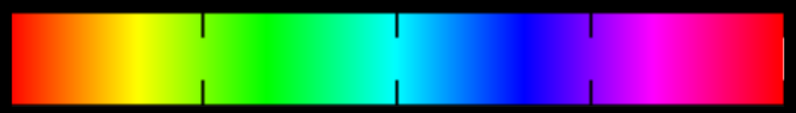
What is ImageJ used for?

Case studies from vascular biology

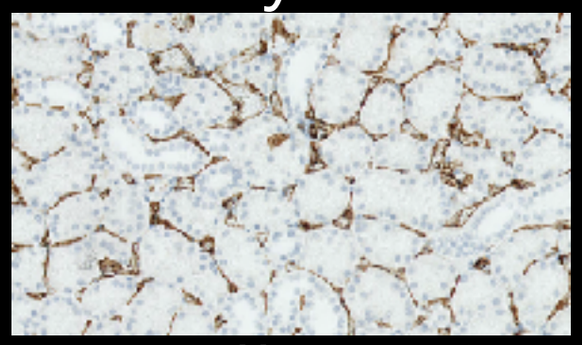
Morphometrics of Human Kidney

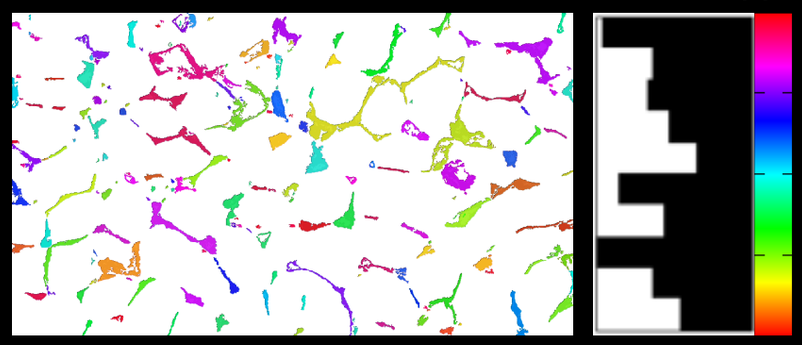
- Regions of the human kidney can be discriminated by morphometric analysis of segmented microvasculature

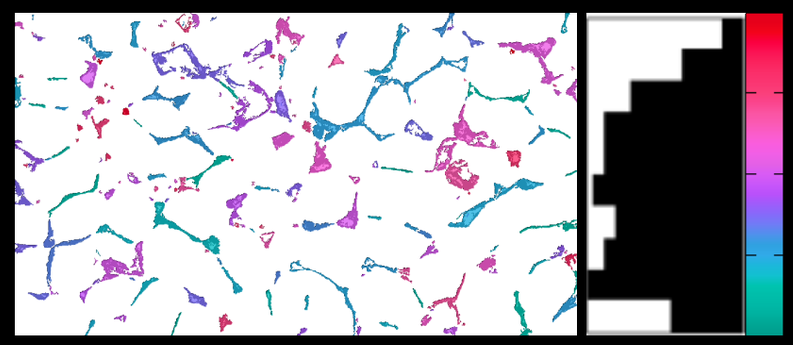


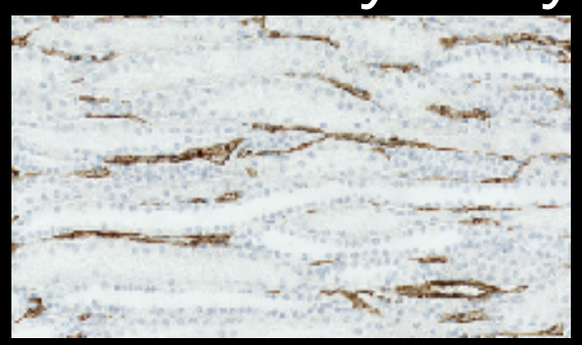


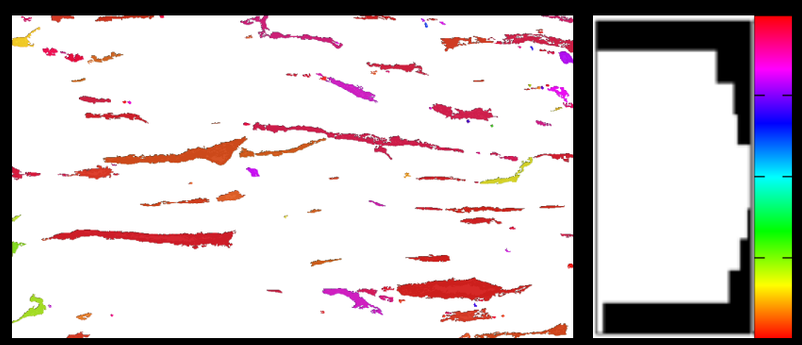


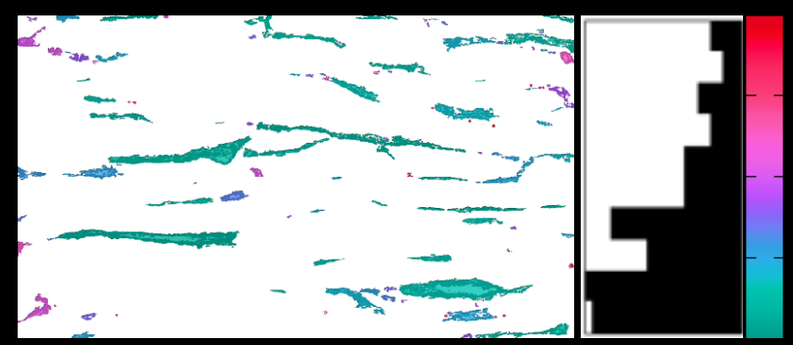










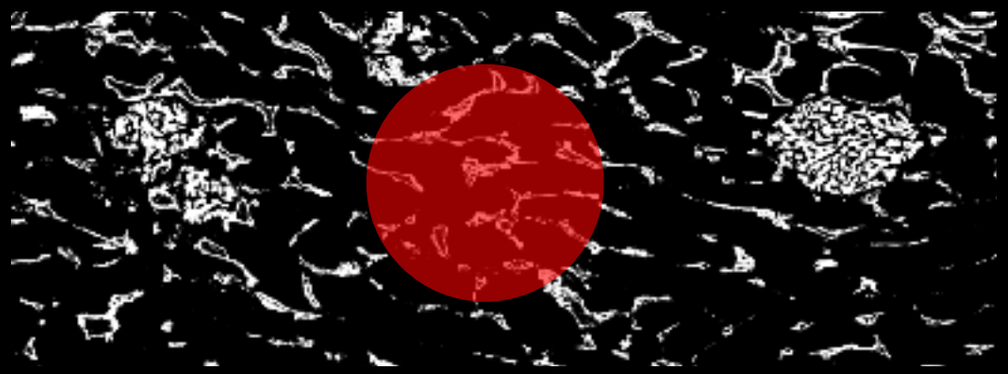


Harrington, K I S, B. E. Faulkner-Jones, K. Bentley, S. Rosen, (2015), Proc. ASN

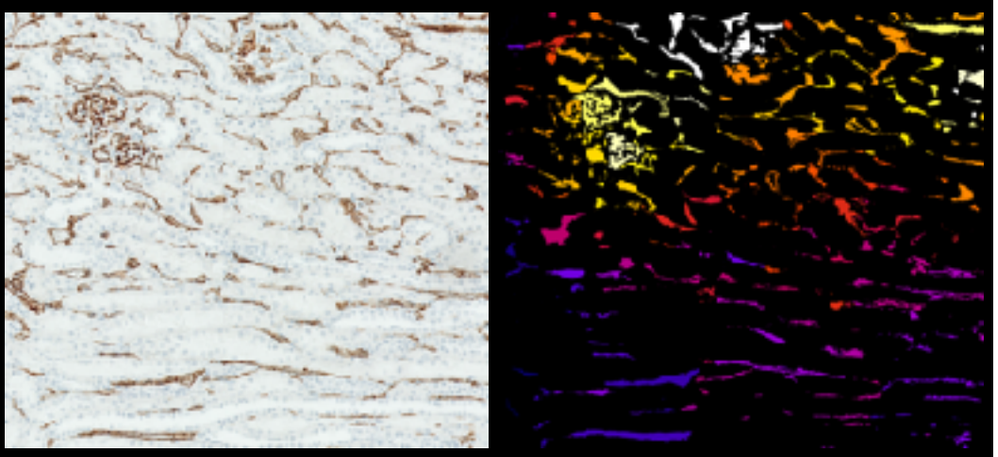
Morphometrics of Kidney Pathology

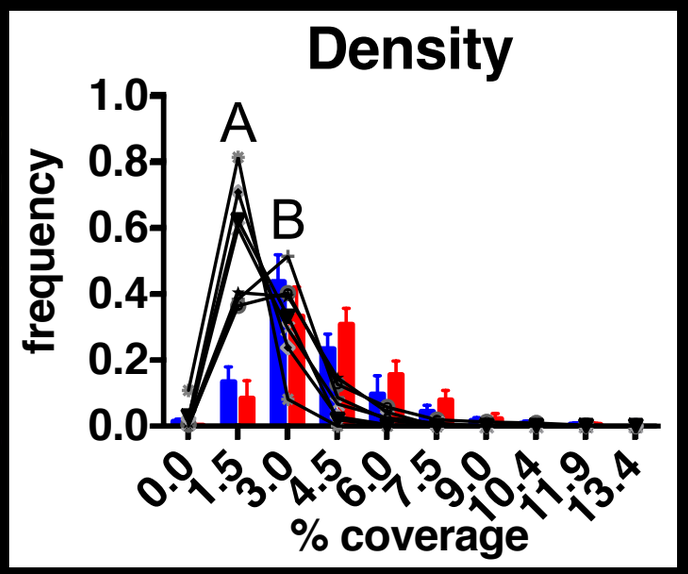
- Pathological human tissue has a signature in microvasculature density

Local Density Calculation

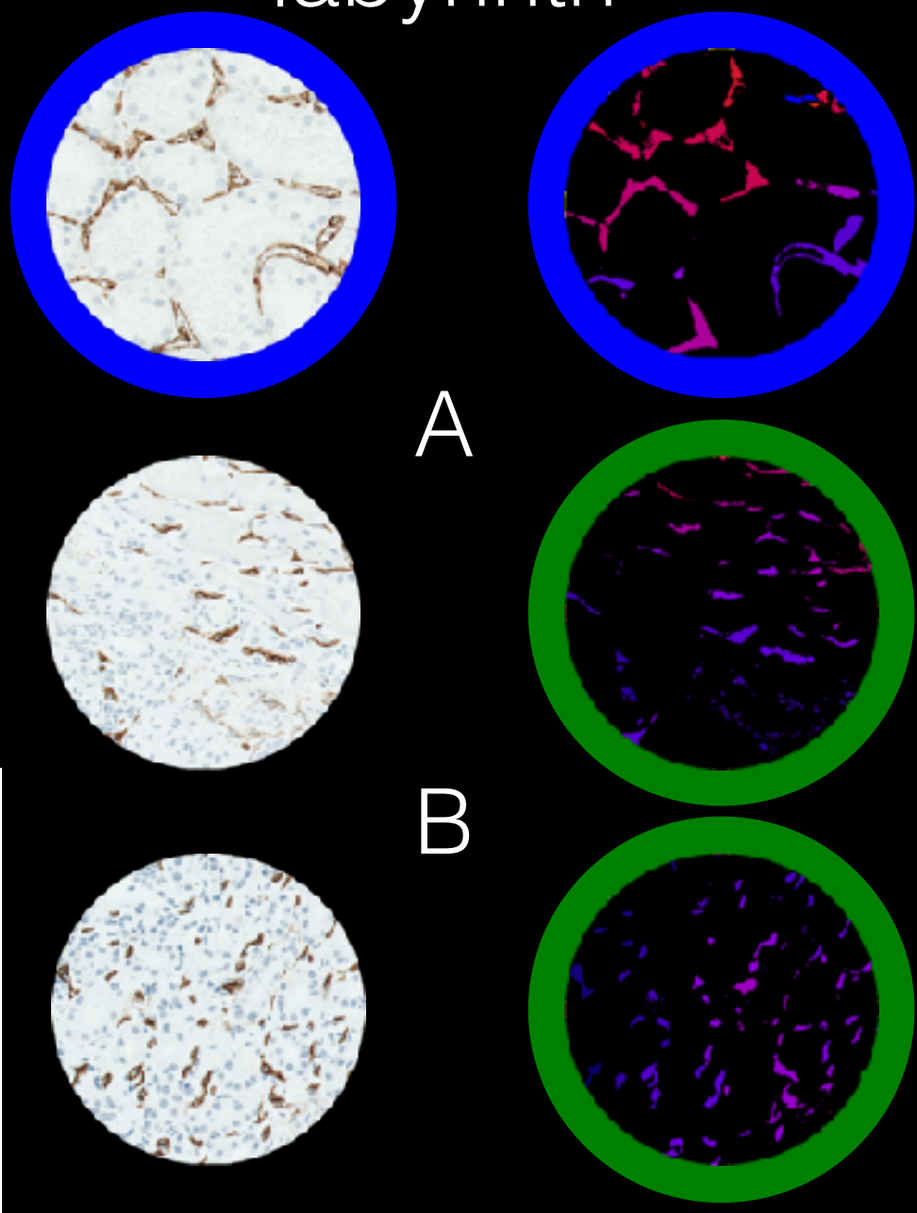


Color-mapped Local Density





Relatively normal labyrinth



Harrington, K I S, B. E. Faulkner-Jones, K. Bentley, S. Rosen, (2015), Proc. ASN

Vascular Development *in vivo*

- Zebrafish as a model of vascular development
- Intersegmental vessels (ISVs) sprout from dorsal aorta to dorsal longitudinal anastomotic vessel

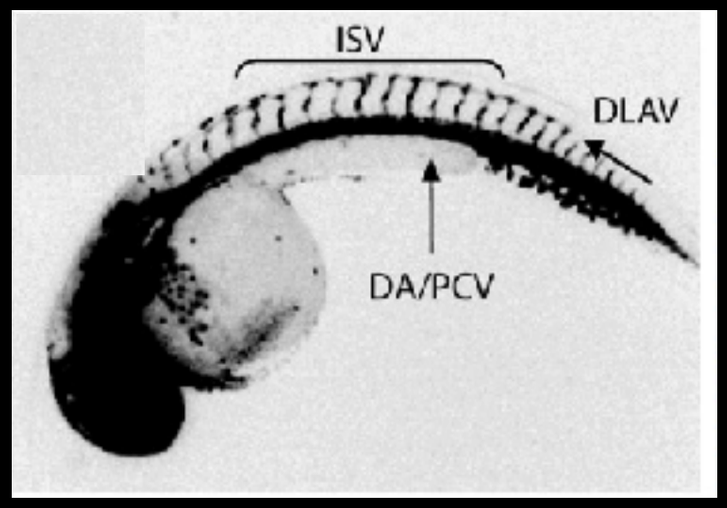
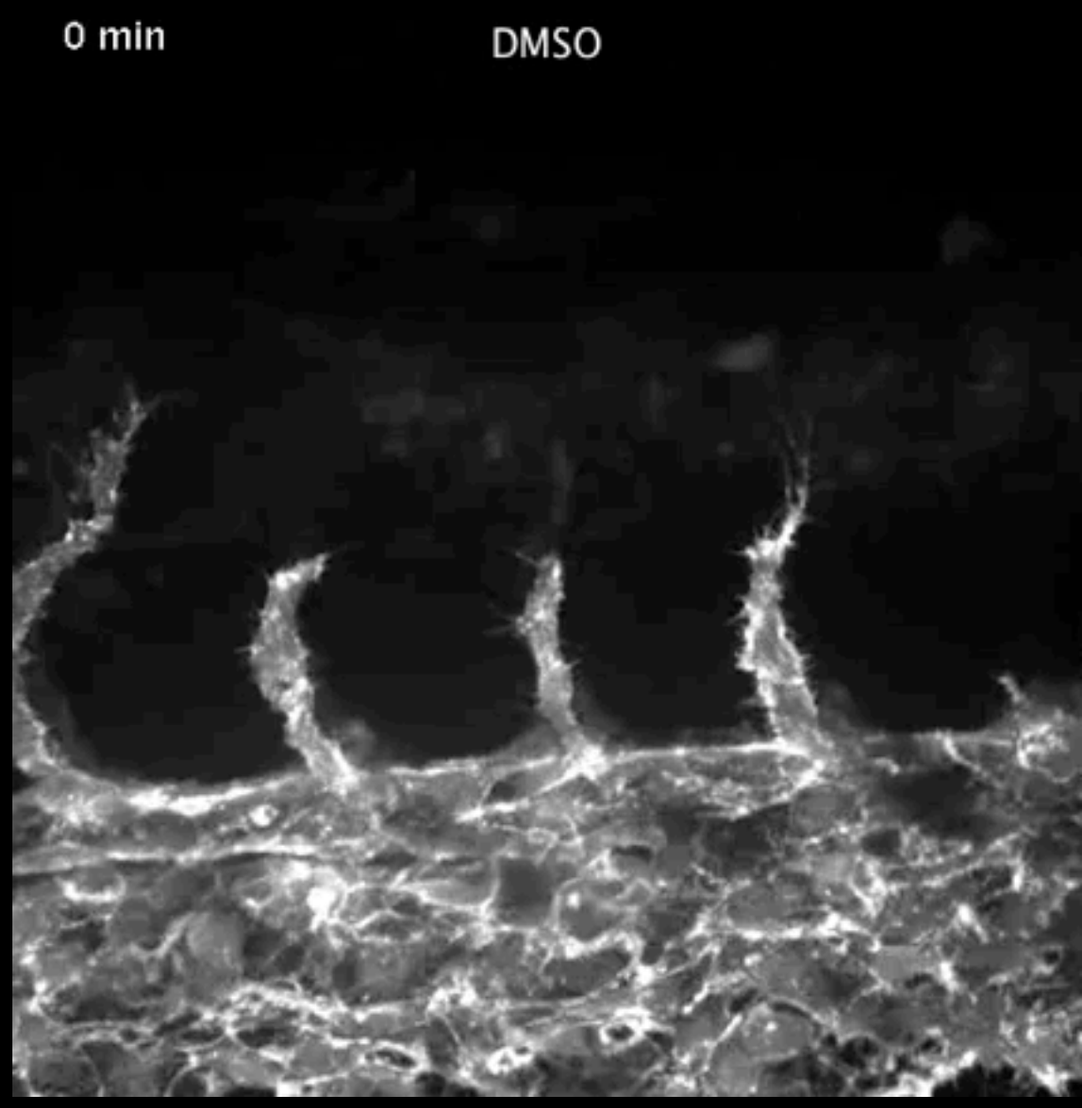
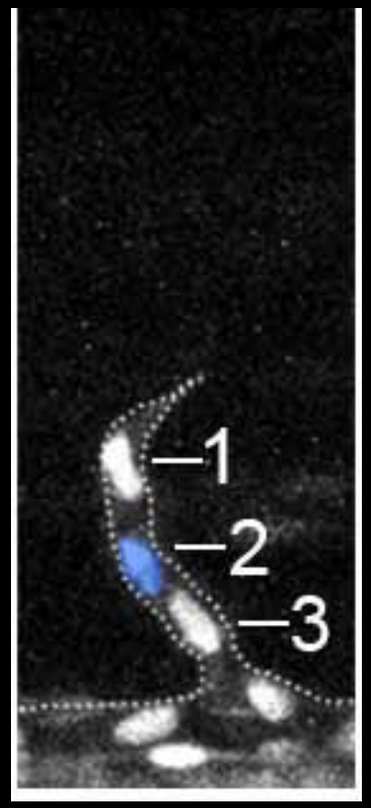


Image: Vogt et al. (2009), Developmental Dynamics.

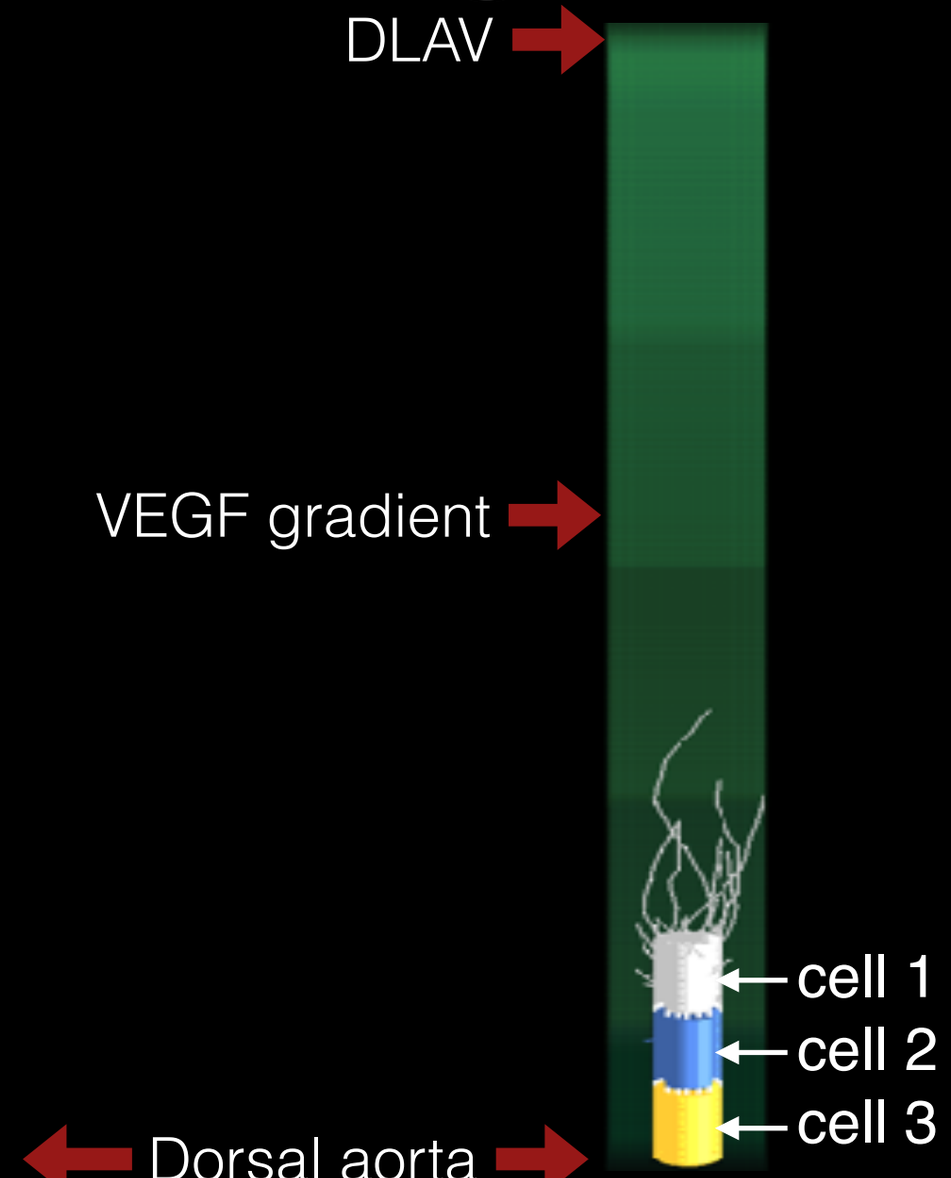


Video: Phng, Stanchi, Gerhardt, (2013) Development.

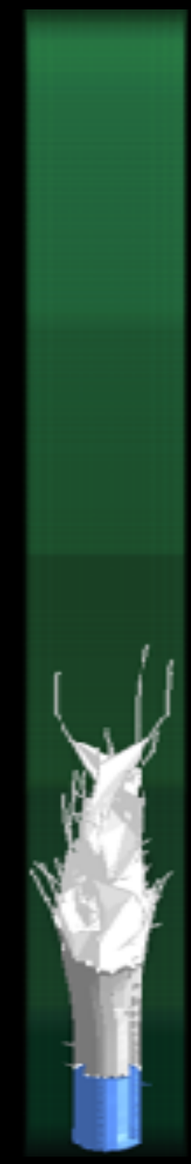
Simulating Zebrafish ISV



Zebrafish ISV



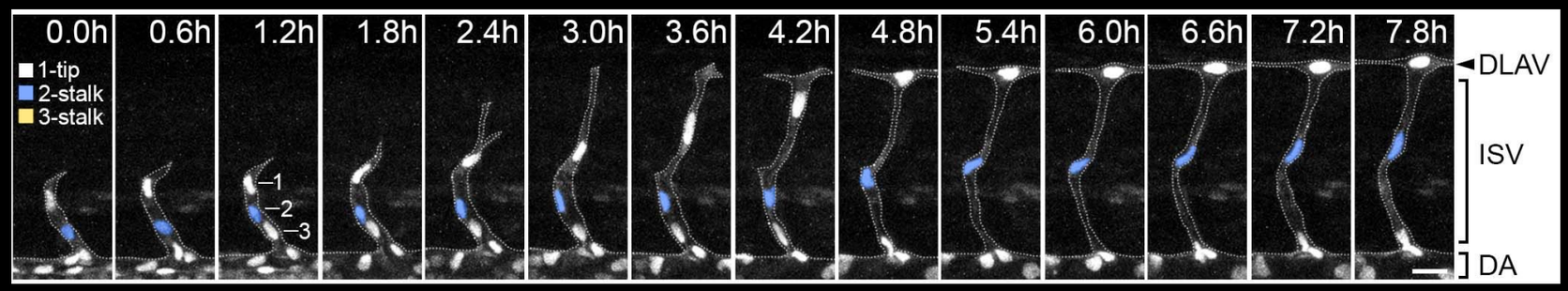
Initialization

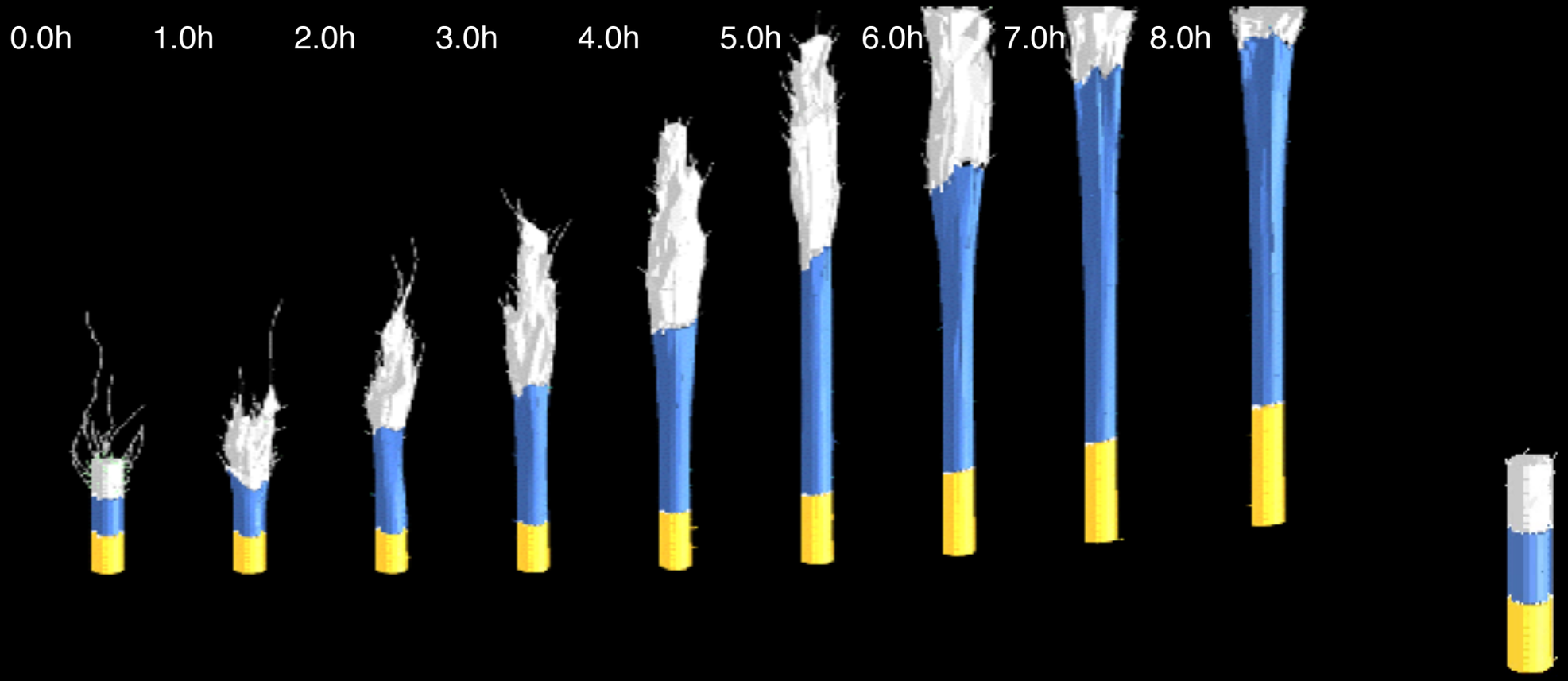


Migration

Costa*, **Harrington***, Page*, …., Herbert, Bentley, (2016) Nature Cell Biology
*Joint Primary Authors.

Wildtype zebrafish ISV development with no divisions

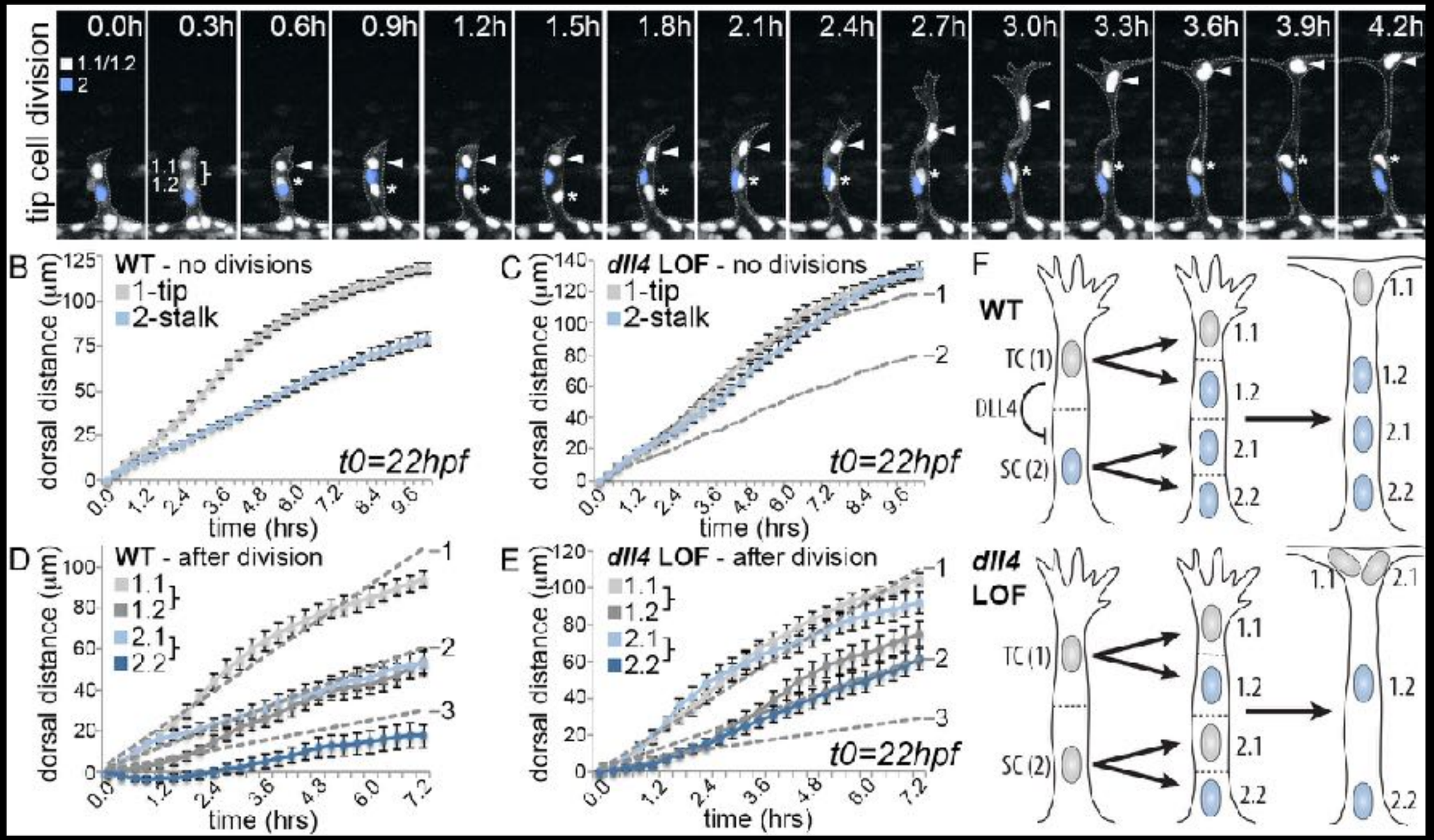




Costa*, **Harrington***, Page*, …., Herbert, Bentley, (2016) Nature Cell Biology

*Joint Primary Authors.

Stereotyped Daughter Behavior in ISV Cell Divisions

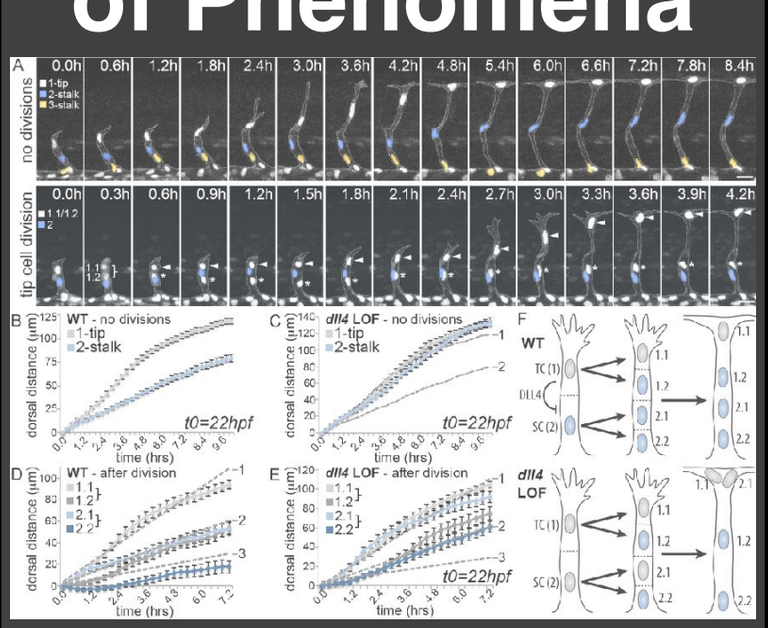


Costa*, **Harrington***, Page*, …., Herbert, Bentley, (2016) Nature Cell Biology

*Joint Primary Authors.

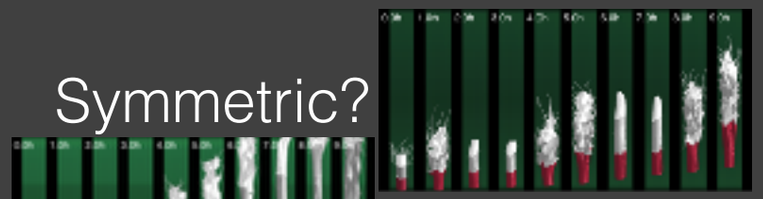
Simulation to Test Hypotheses

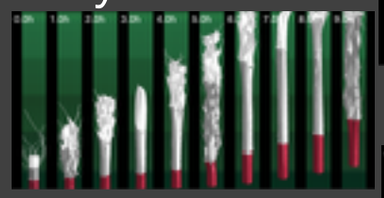
Experimental Observation of Phenomena



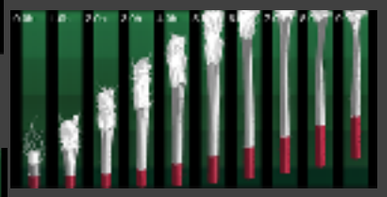
Test Hypotheses

Symmetric?

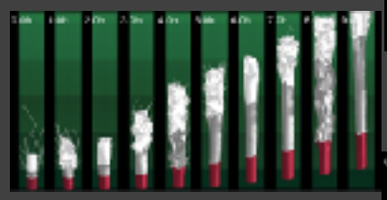




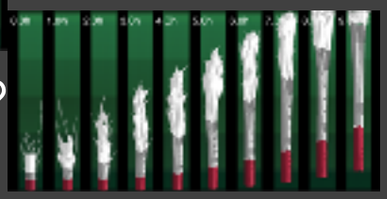
Protein?



mRNA?

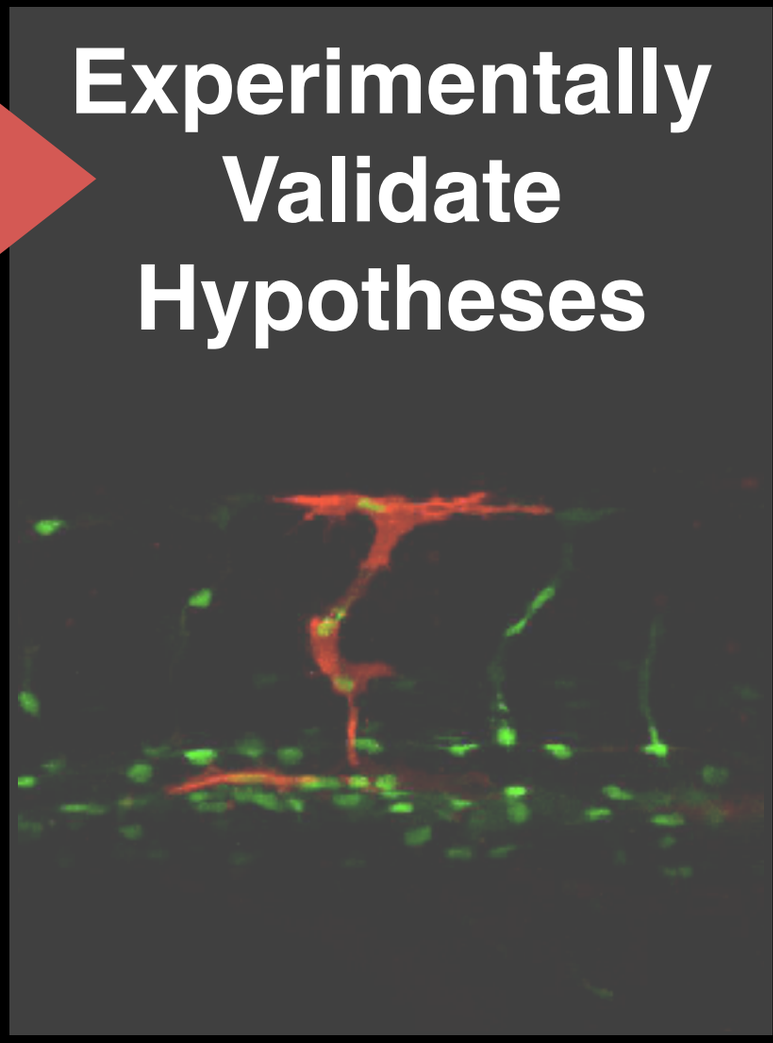


Cell size?



Everything?

Experimentally Validate Hypotheses

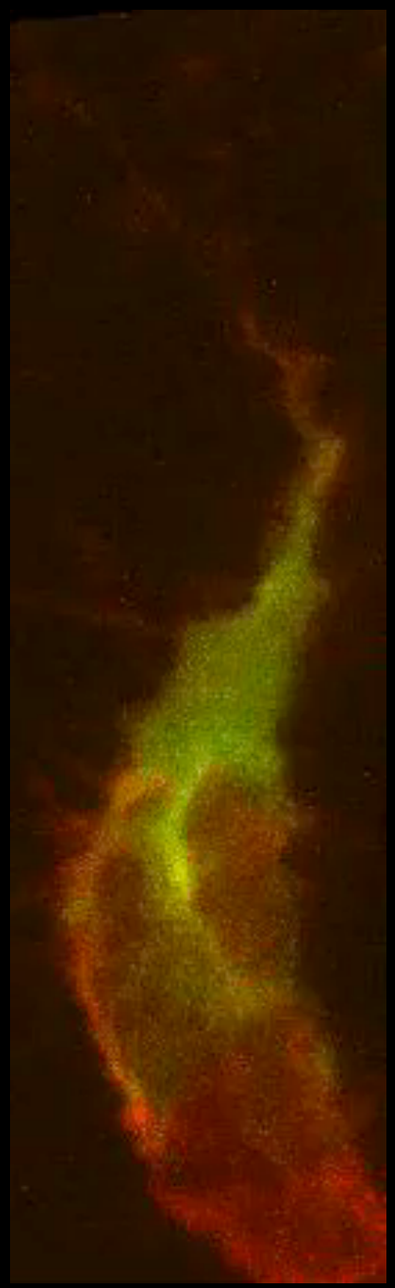


Costa*, **Harrington***, Page*, …., Bentley, Herbert, (Accepted) Nature Cell Biology

*Joint Primary Authors.

Cell Division in Zebrafish ISV
Asymmetric size & mRNA

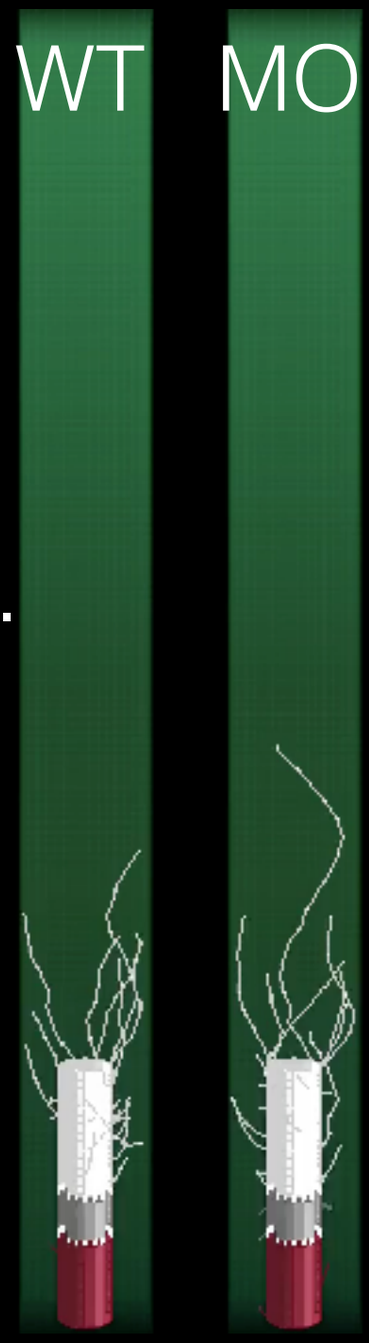
Cell Division
in vivo



Are both daughter cells symmetric in morphology and chemistry?



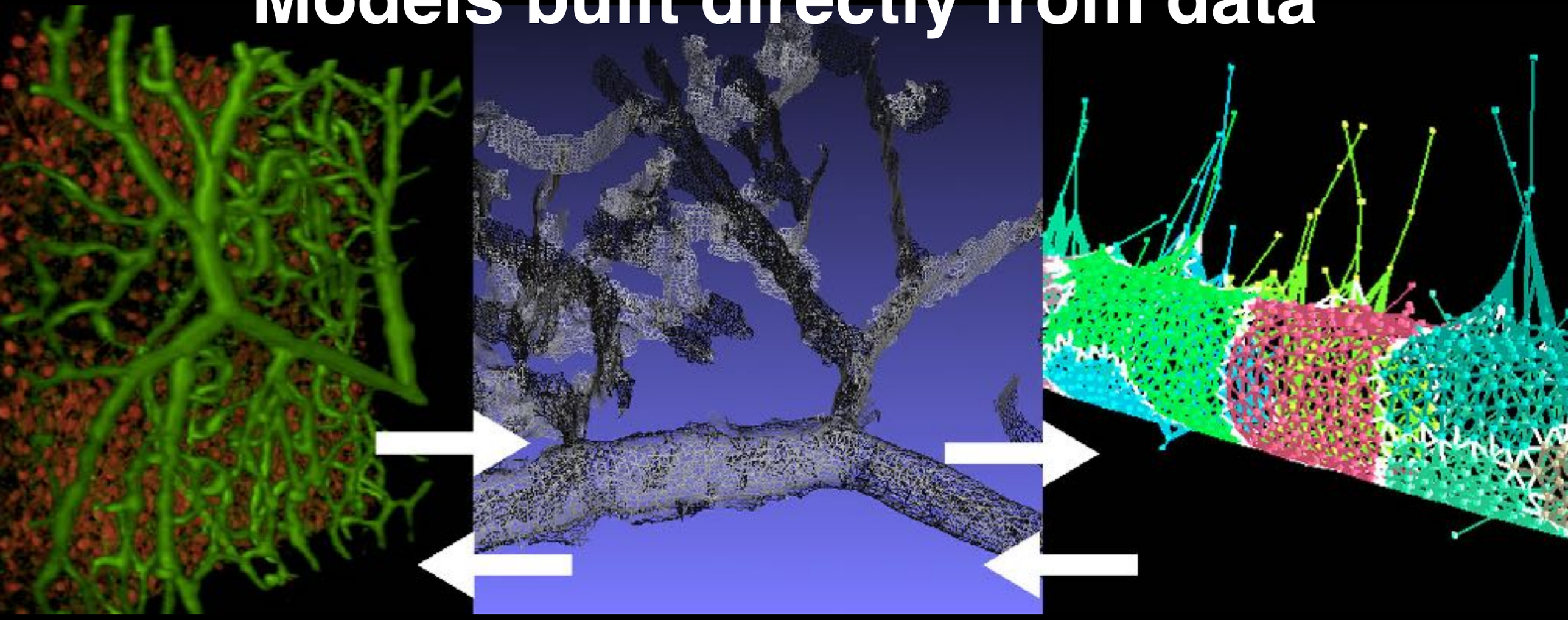
No, the dorsal daughter is **larger** and contains **more VEGFR-2 mRNA**. This allows the dorsal daughter to **move faster** and maintain position in ISV.



Costa*, **Harrington***, Page*, …., Herbert, Bentley, (2016) Nature Cell Biology
*Joint Primary Authors.

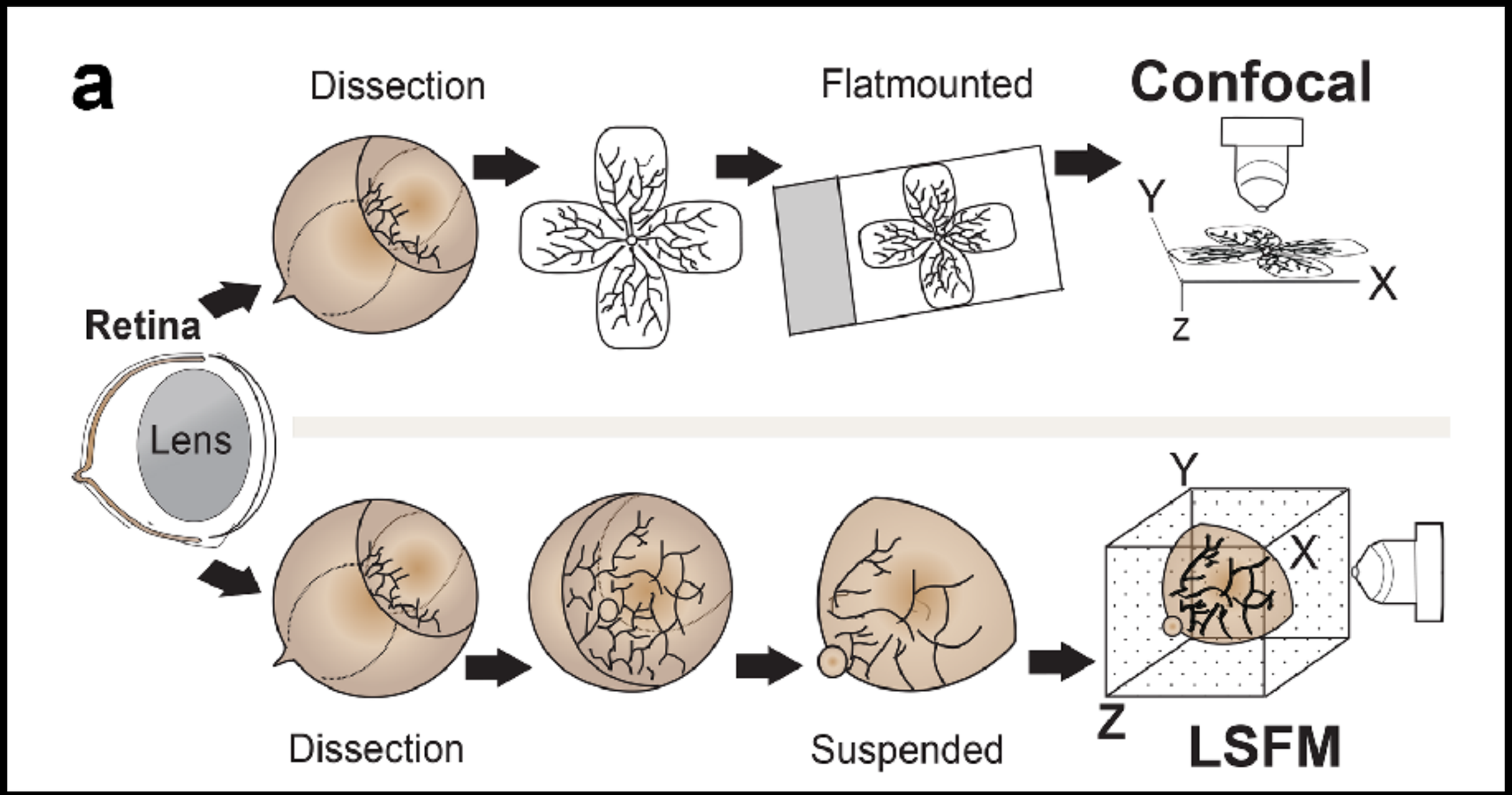
Image-driven Simulation

Models built directly from data



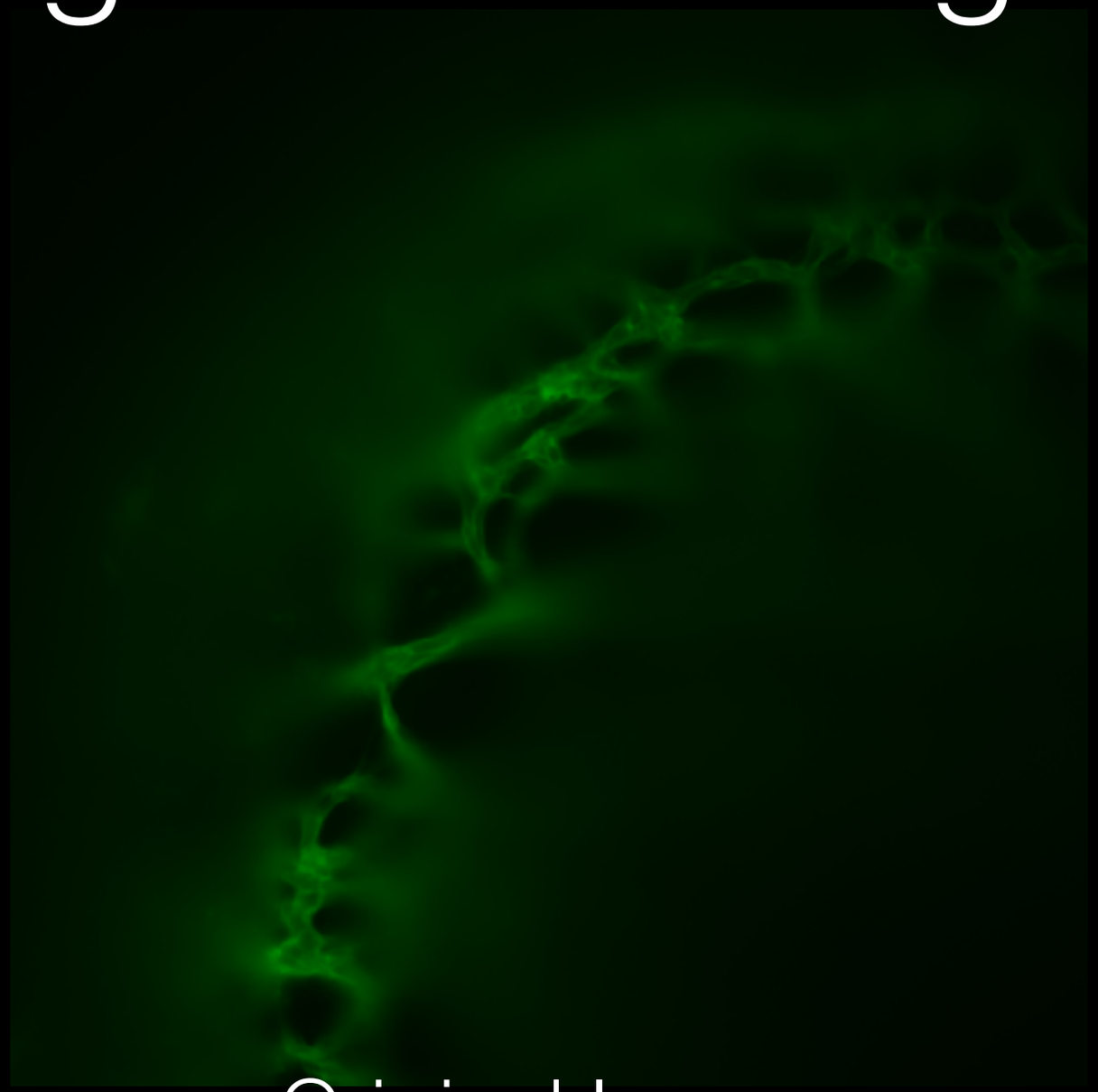
Predictive models inform experiments

Minimizing Tissue Manipulation with Lightsheet Microscopy



Prahst, **Harrington**, Venkatraman, Bentley (under review)

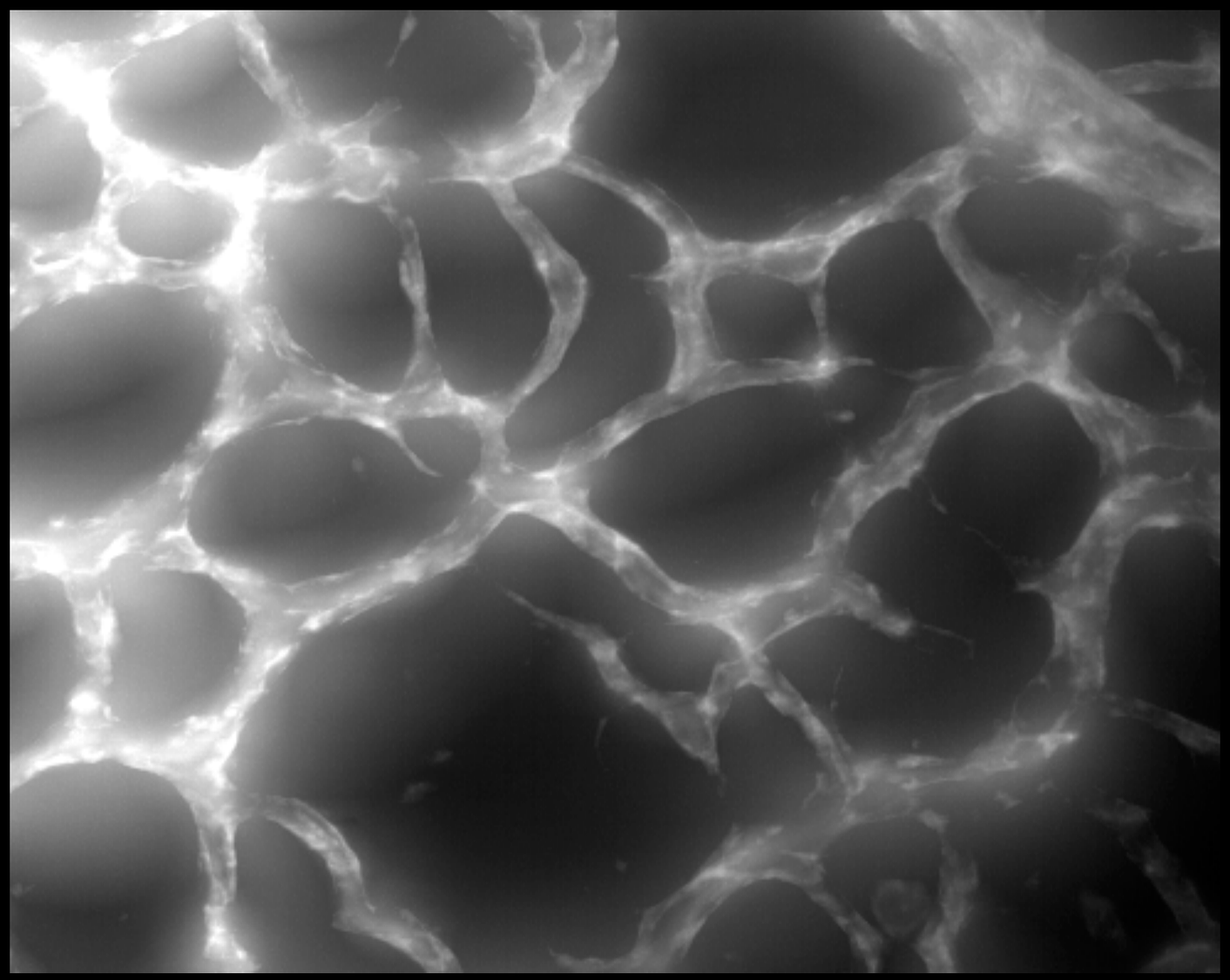
Extracting Structures from Lightsheet Images



Original Image
Mouse Retina, Isolectin B4

Prahst, **Harrington**, Venkatraman, Bentley (under review)

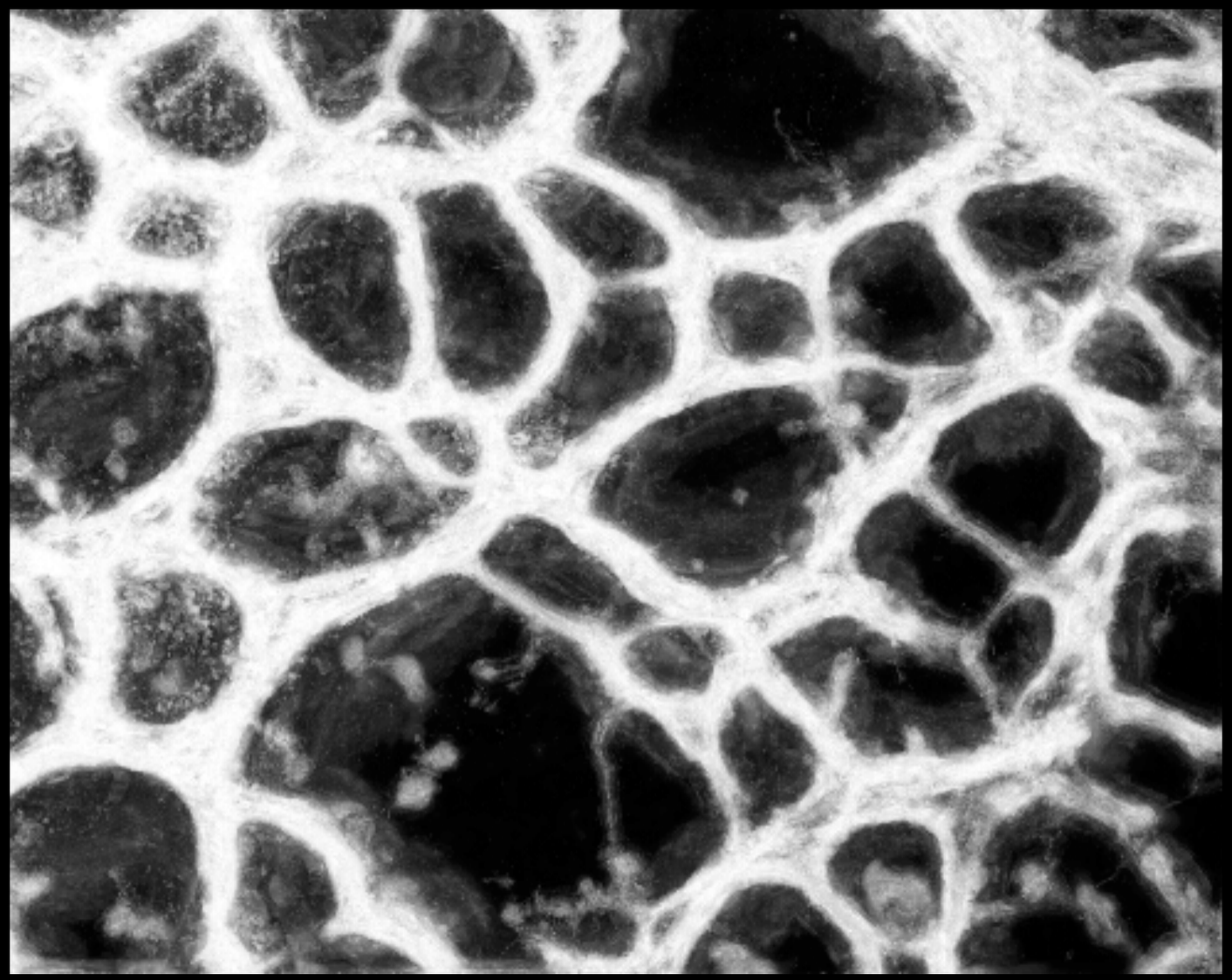
Extracting Structures from Lightsheet Images



Original Image (max projection)
Mouse Retina, Isolectin B4

Prahst, **Harrington**, Venkatraman, Bentley (under review)

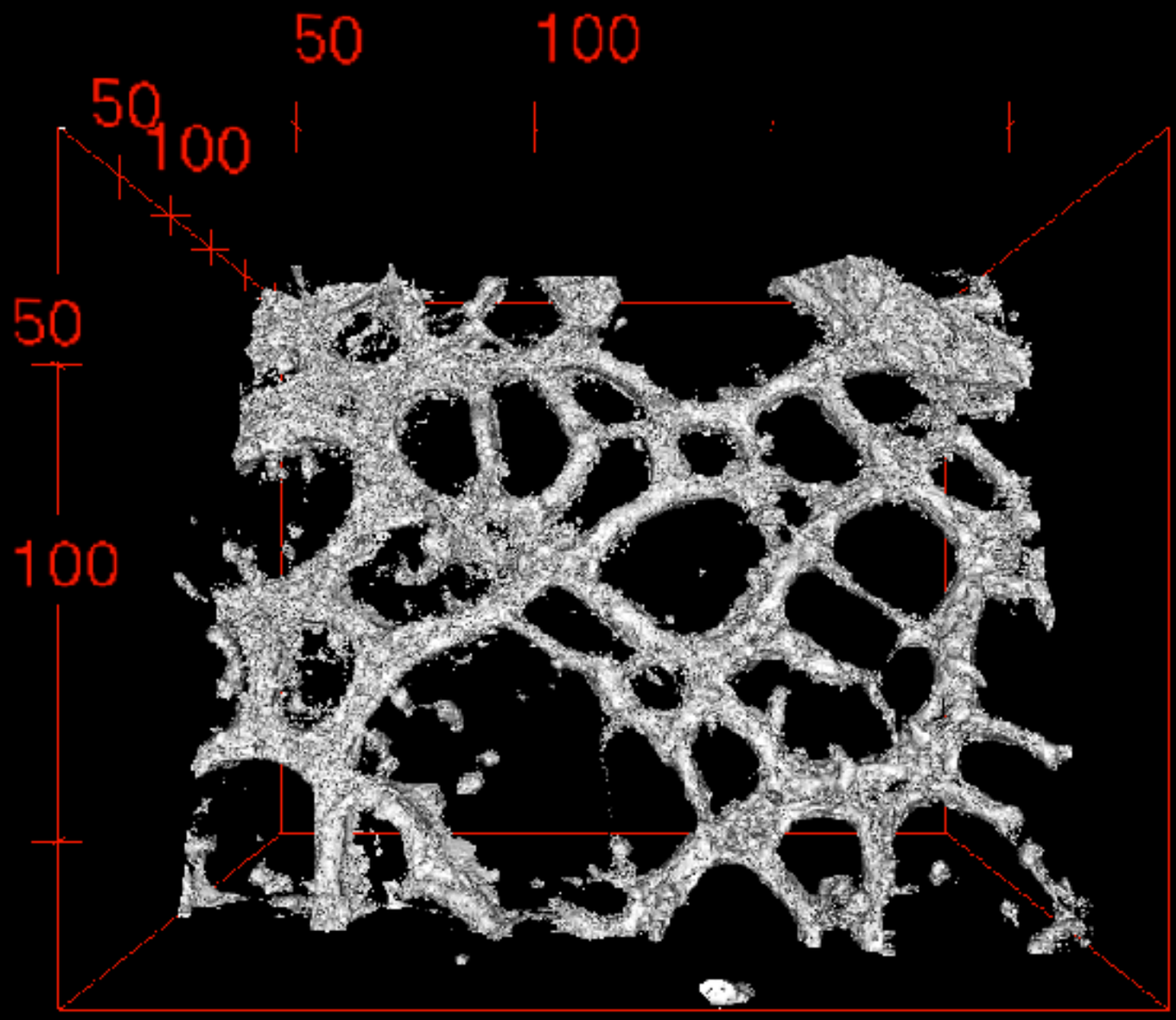
Extracting Structures from Lightsheet Images



Semiautomated Segmentation
Ilastik

Prahst, **Harrington**, Venkatraman, Bentley (under review)

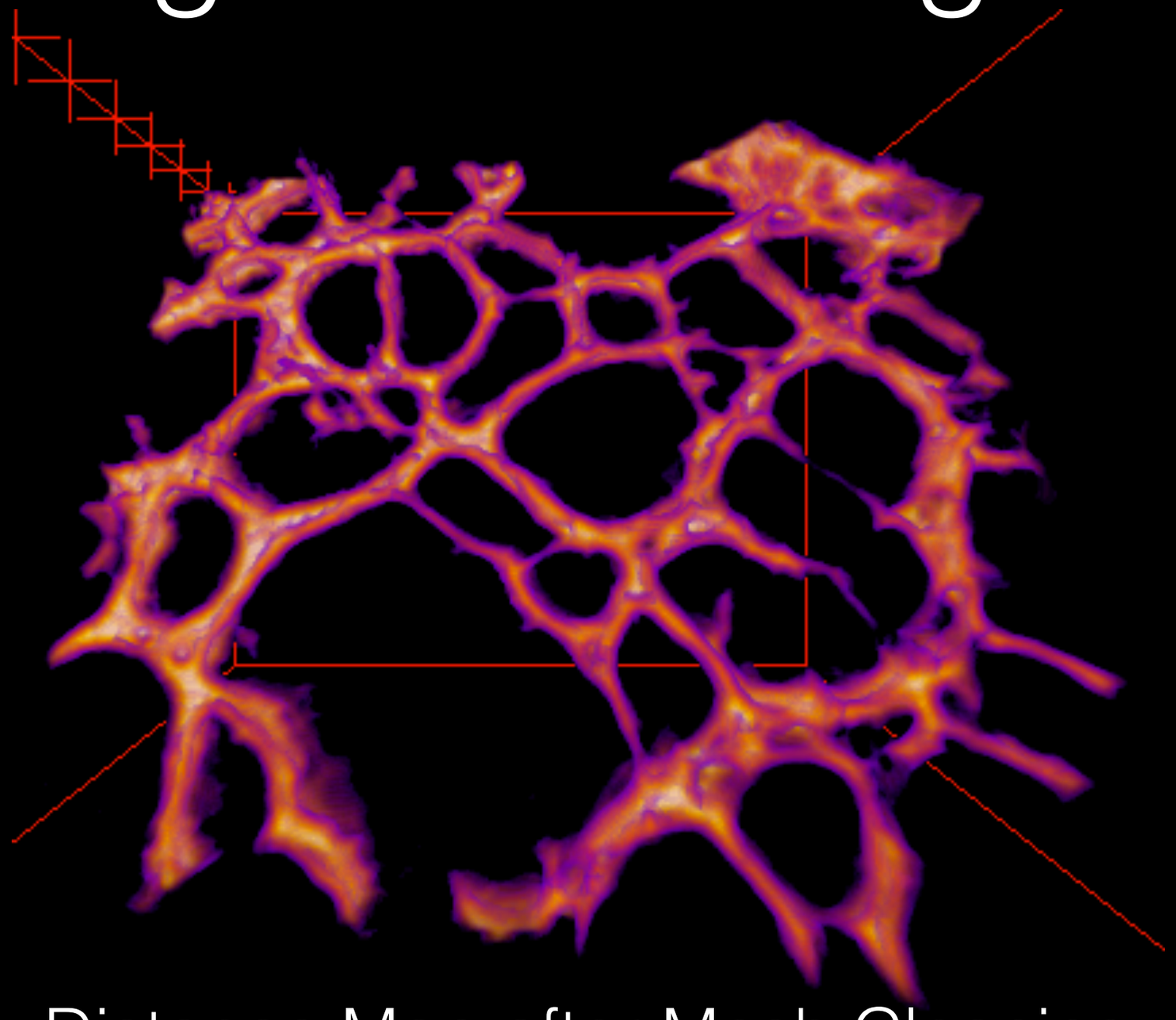
Extracting Structures from Lightsheet Images



Surface Mesh of Segmentation

Prahst, **Harrington**, Venkatraman, Bentley (under review)

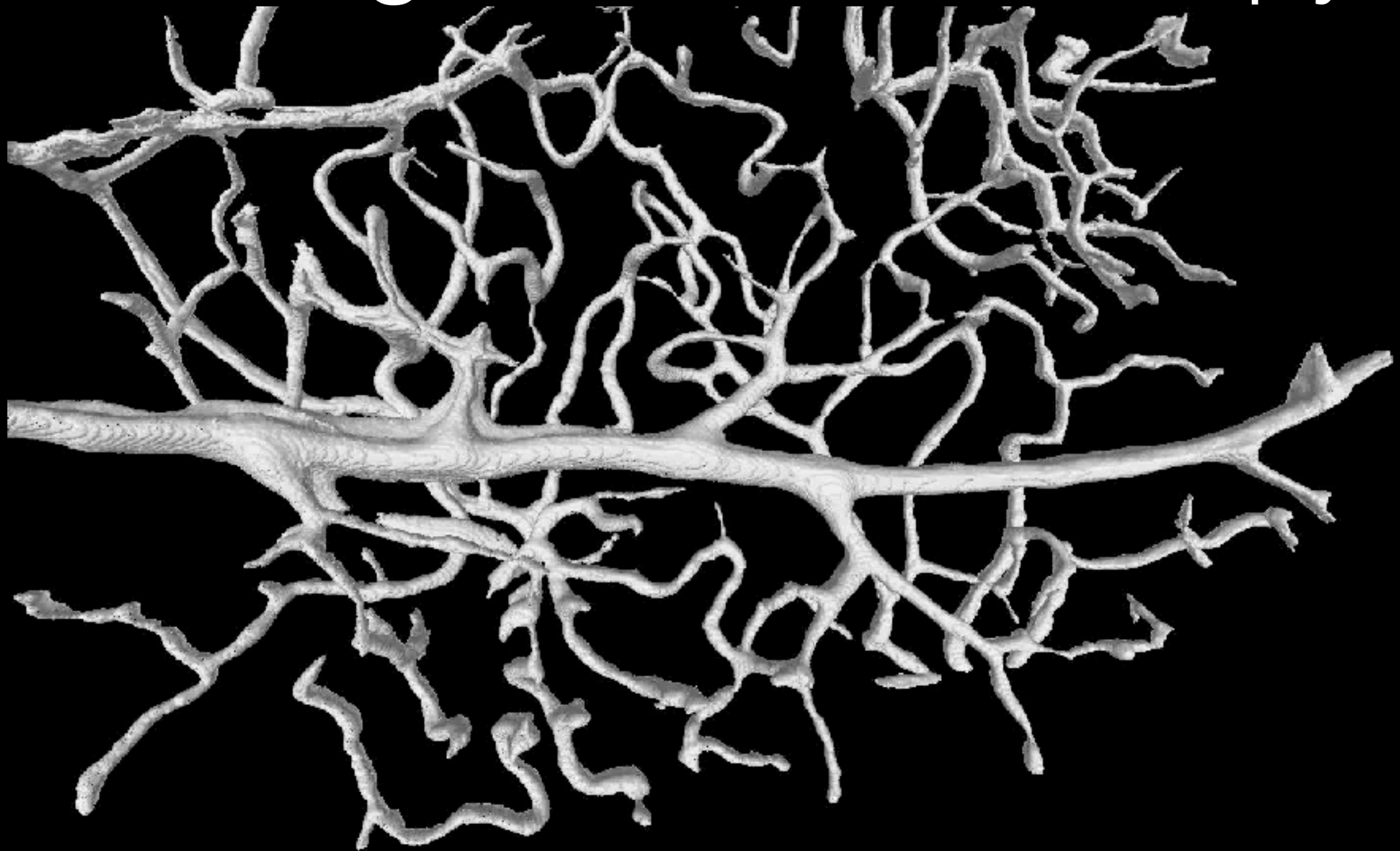
Extracting Structures from Lightsheet Images



Distance Map after Mesh Cleaning

Prahst, **Harrington**, Venkatraman, Bentley (under review)

3D Vascular Morphology from Lightsheet Microscopy

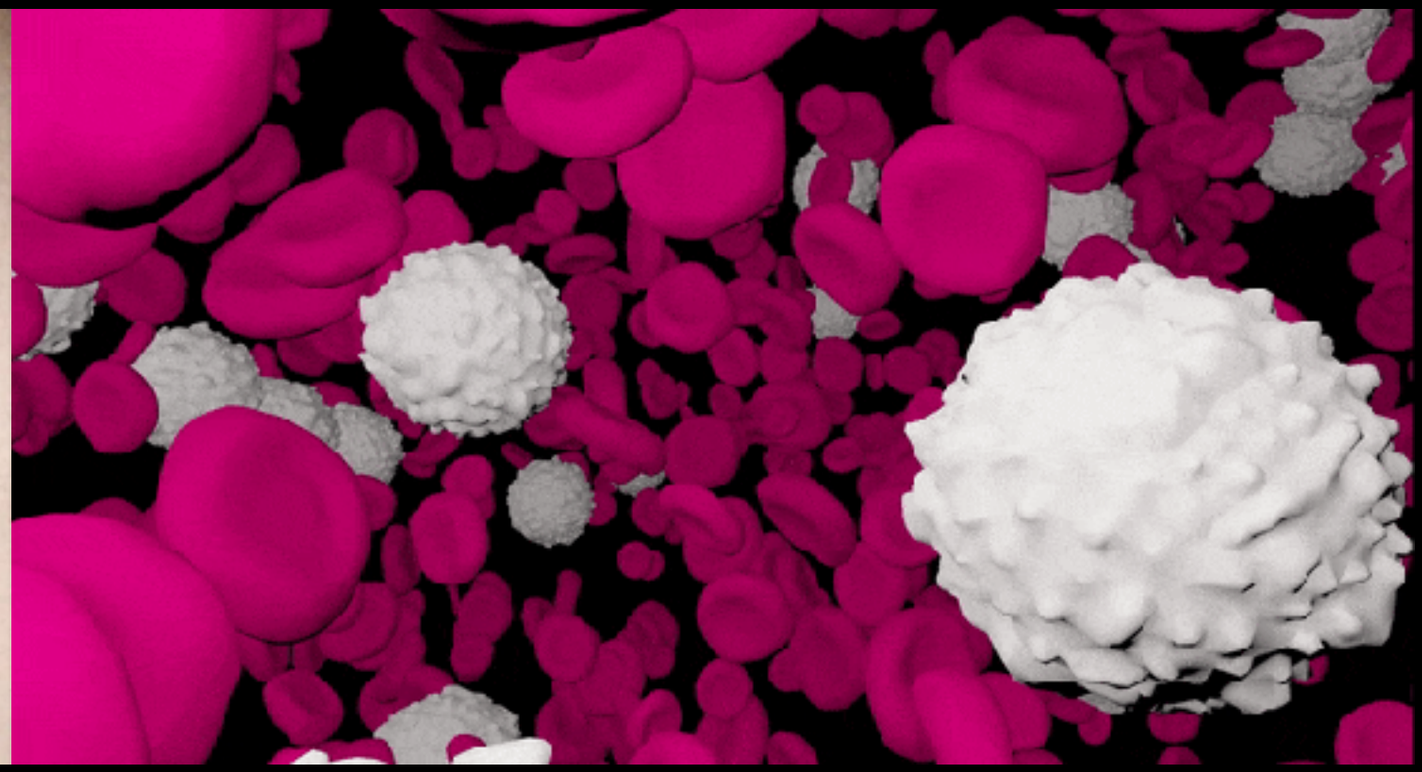


Prahst, **Harrington**, Venkatraman, Bentley (under review)

What's Coming?

- Real-time virtual reality for visualization and simulation of biological tissues





with Ulrik Günther and Ivo Sbalzarini

- KNIME Seattle Meetup, May 8 (knime.com)

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ImageJ: web: http://imagej.net forum: http://forum.imagej.net

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