Classifying the Histomorphology of Prostatic Adenocarcinoma with Deep Neural Networks

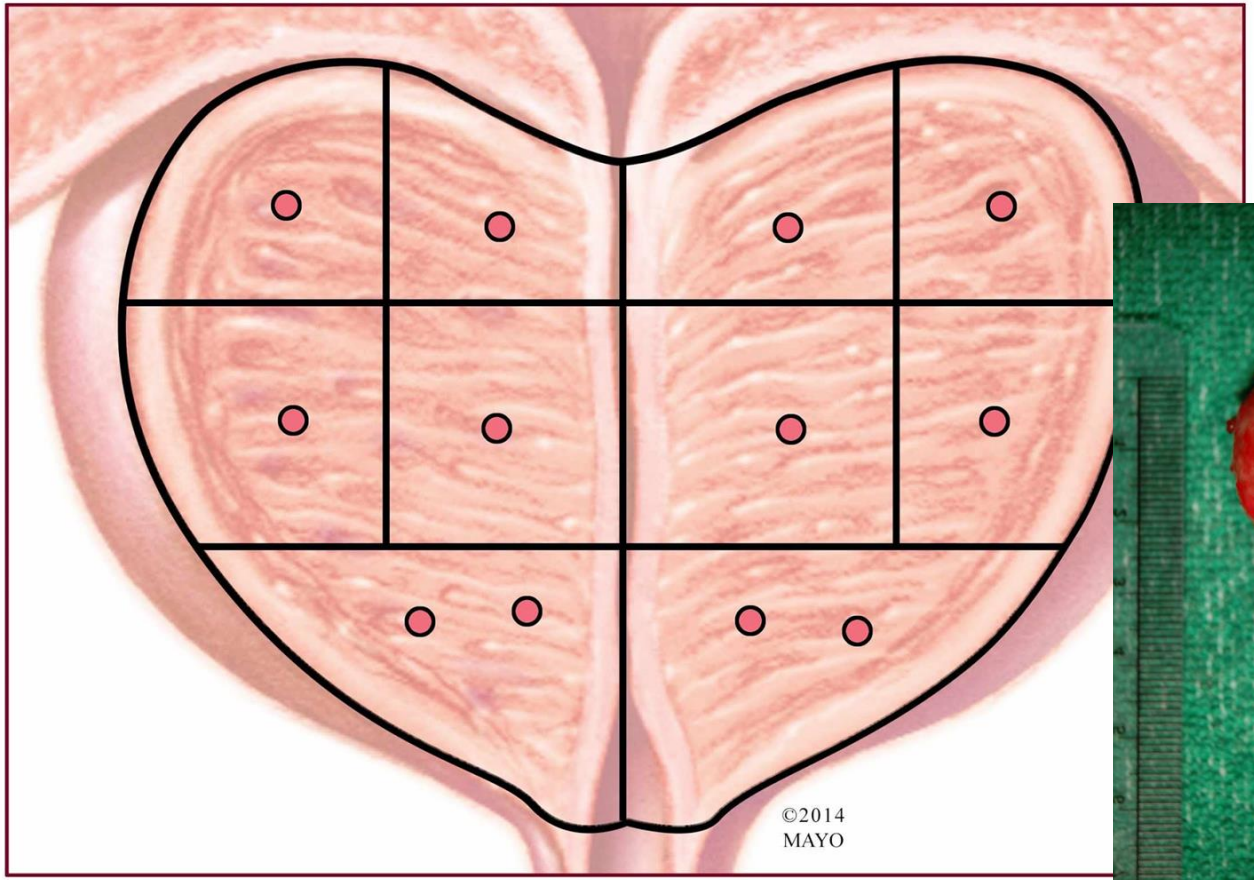
Teaching a Machine to Diagnose Cancer

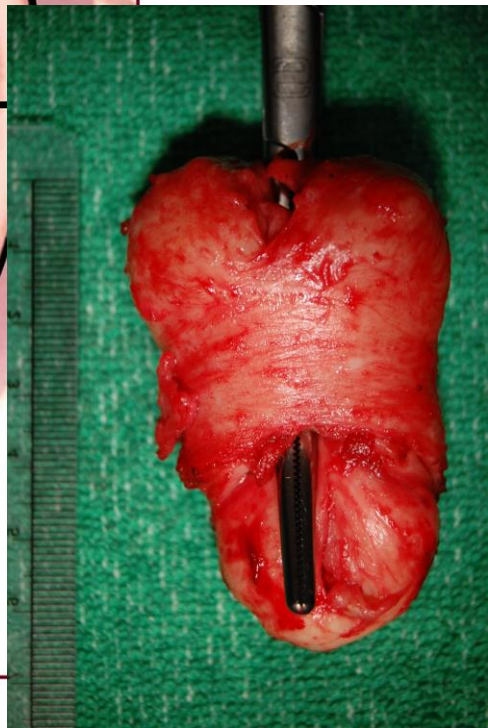
I have no conflicts of interest

The views expressed are those of the author and do not reflect the official policy or position of the Department of the Navy, the Department of Defense, or the United States Government.

The Problem

Prostate biopsy pattern





Zoom
Fit
1X
2X
4X
5X
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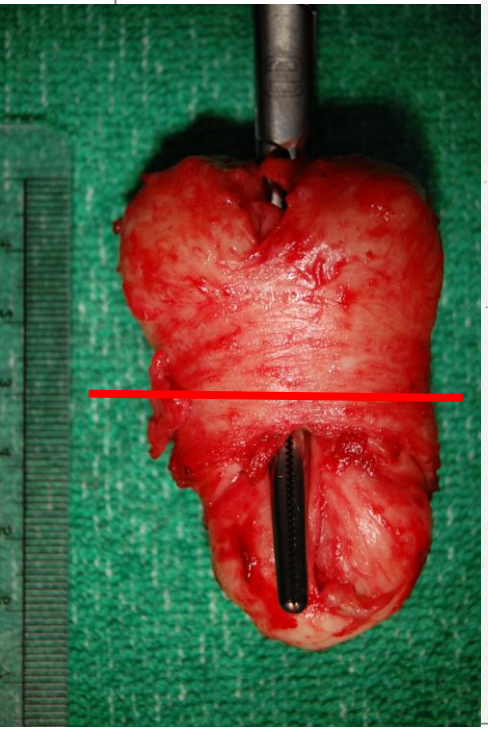
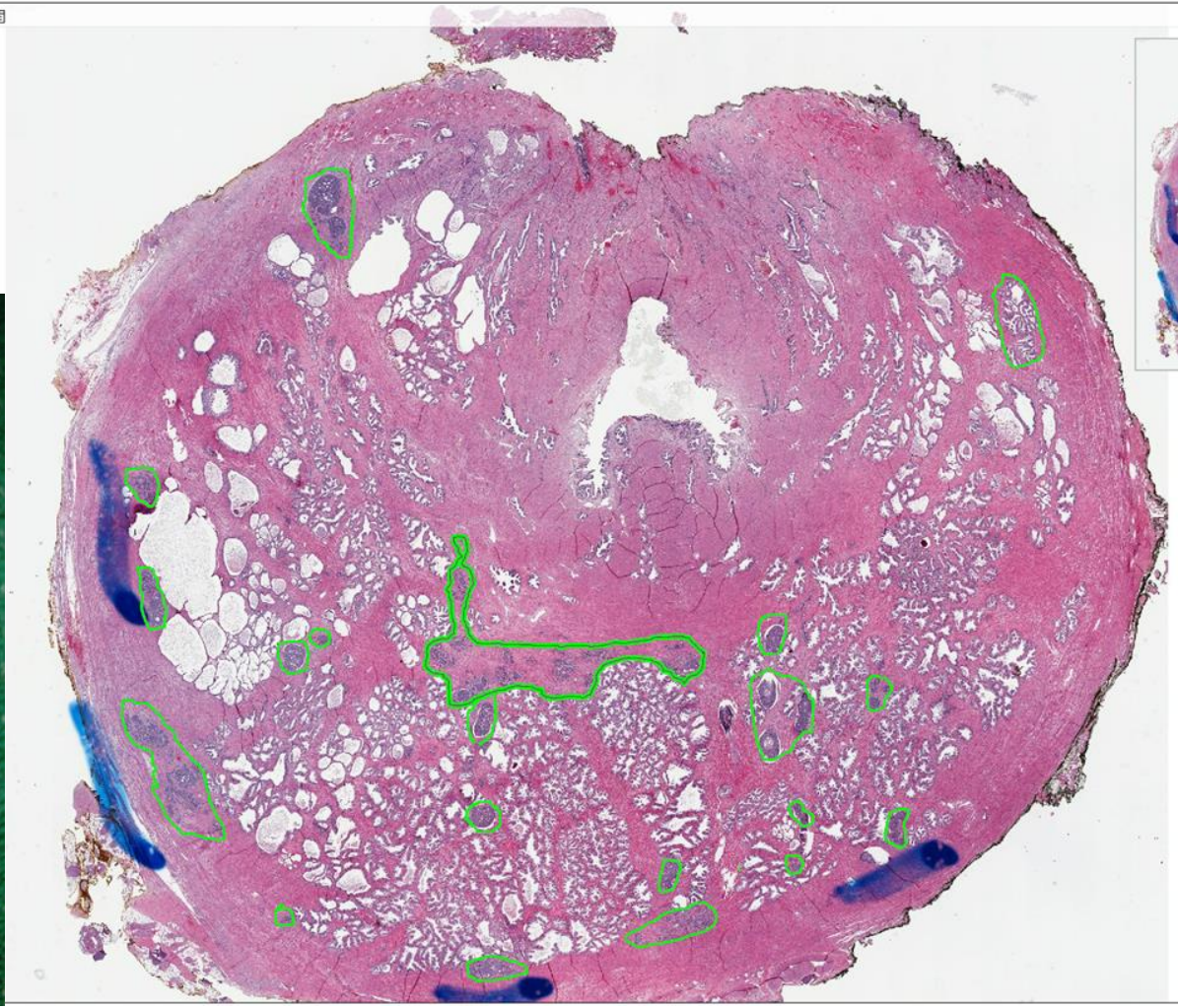
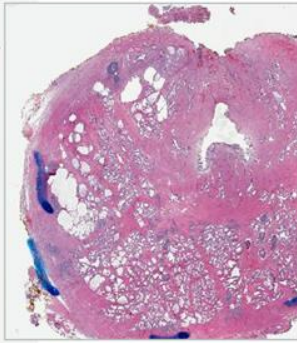
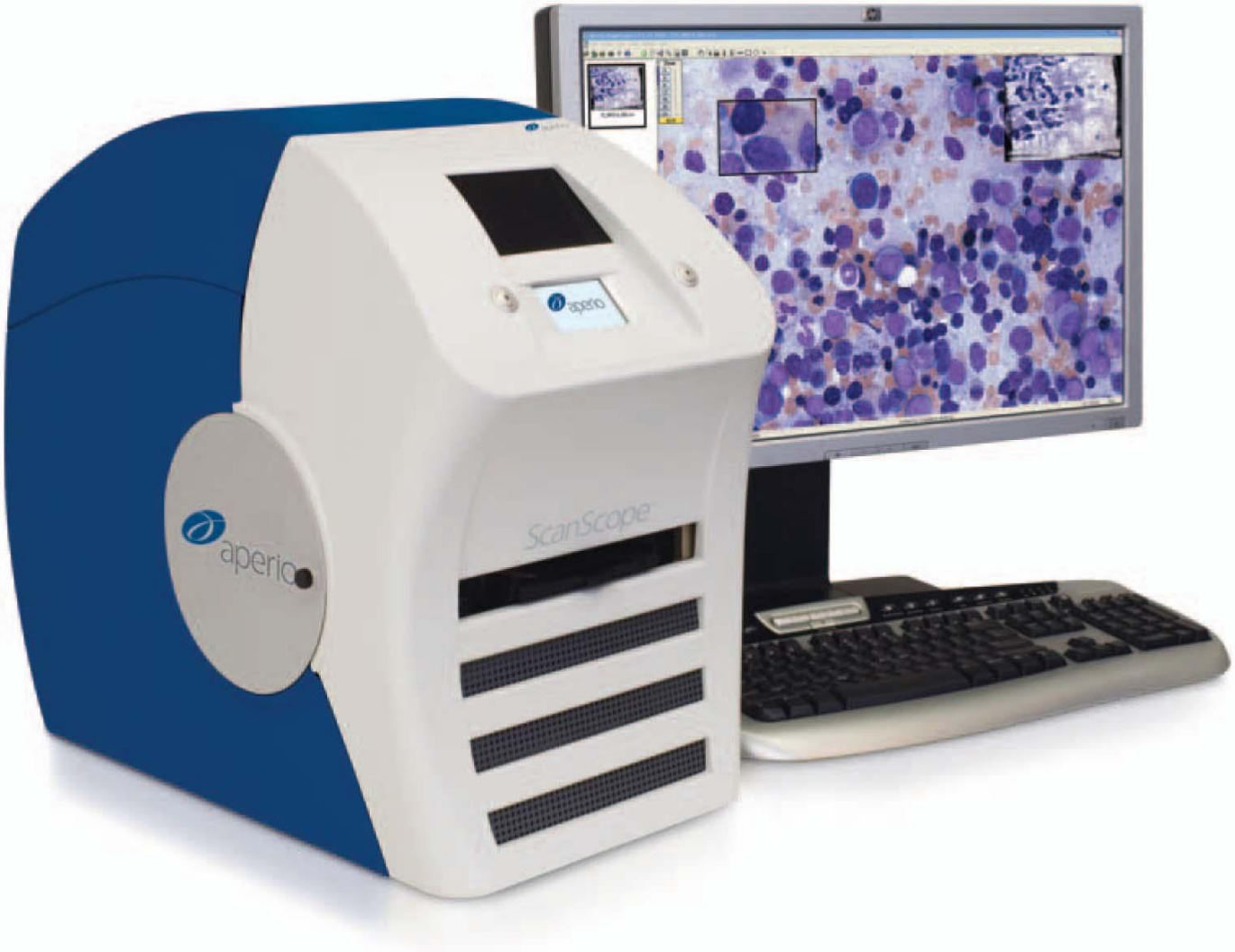
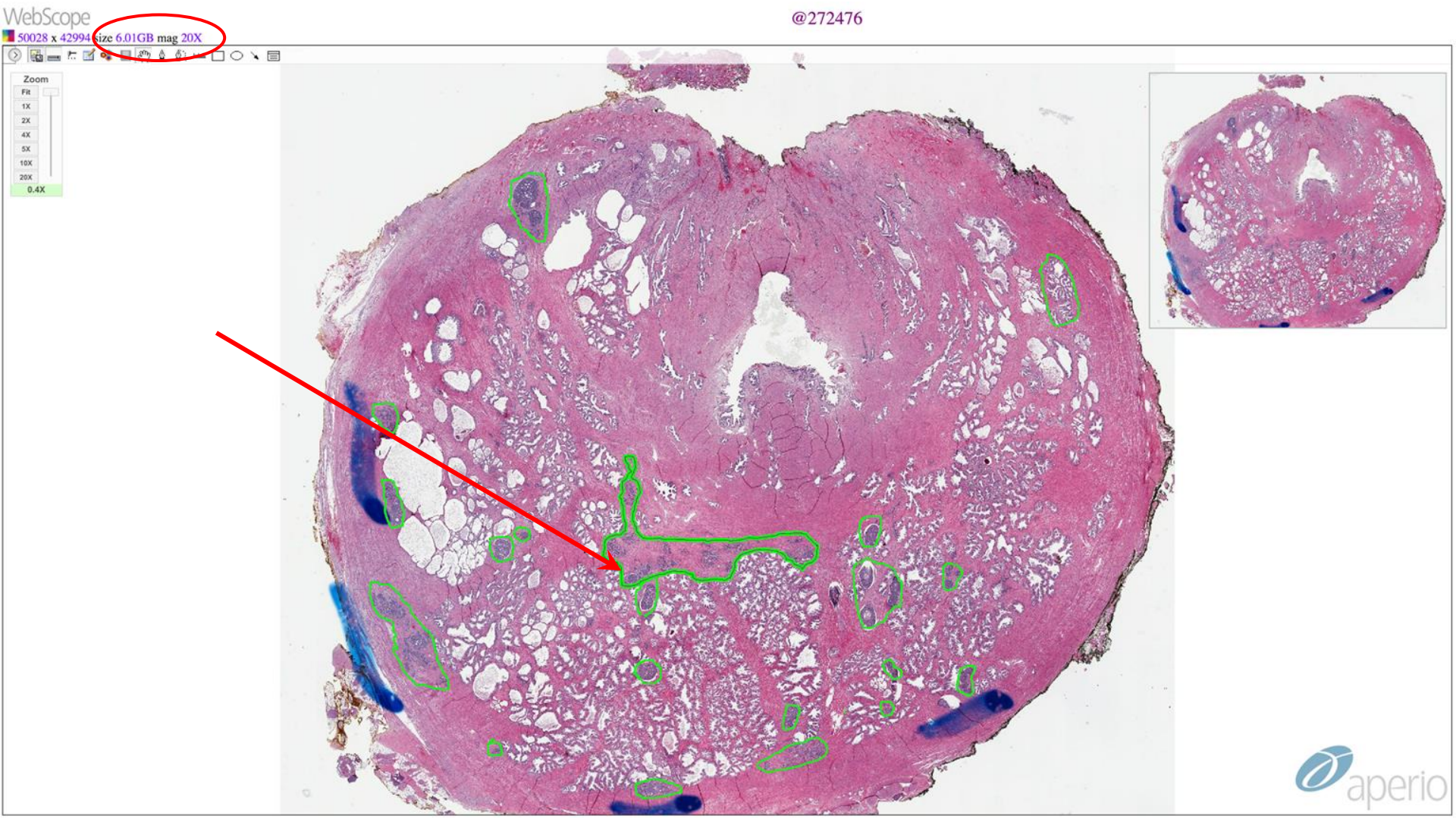
20X
0.4X








aperio
ScanScope
aperio


WebScope
50028 x 42994 size 6.01GB mag 20X
@272476
Zoom
Fit
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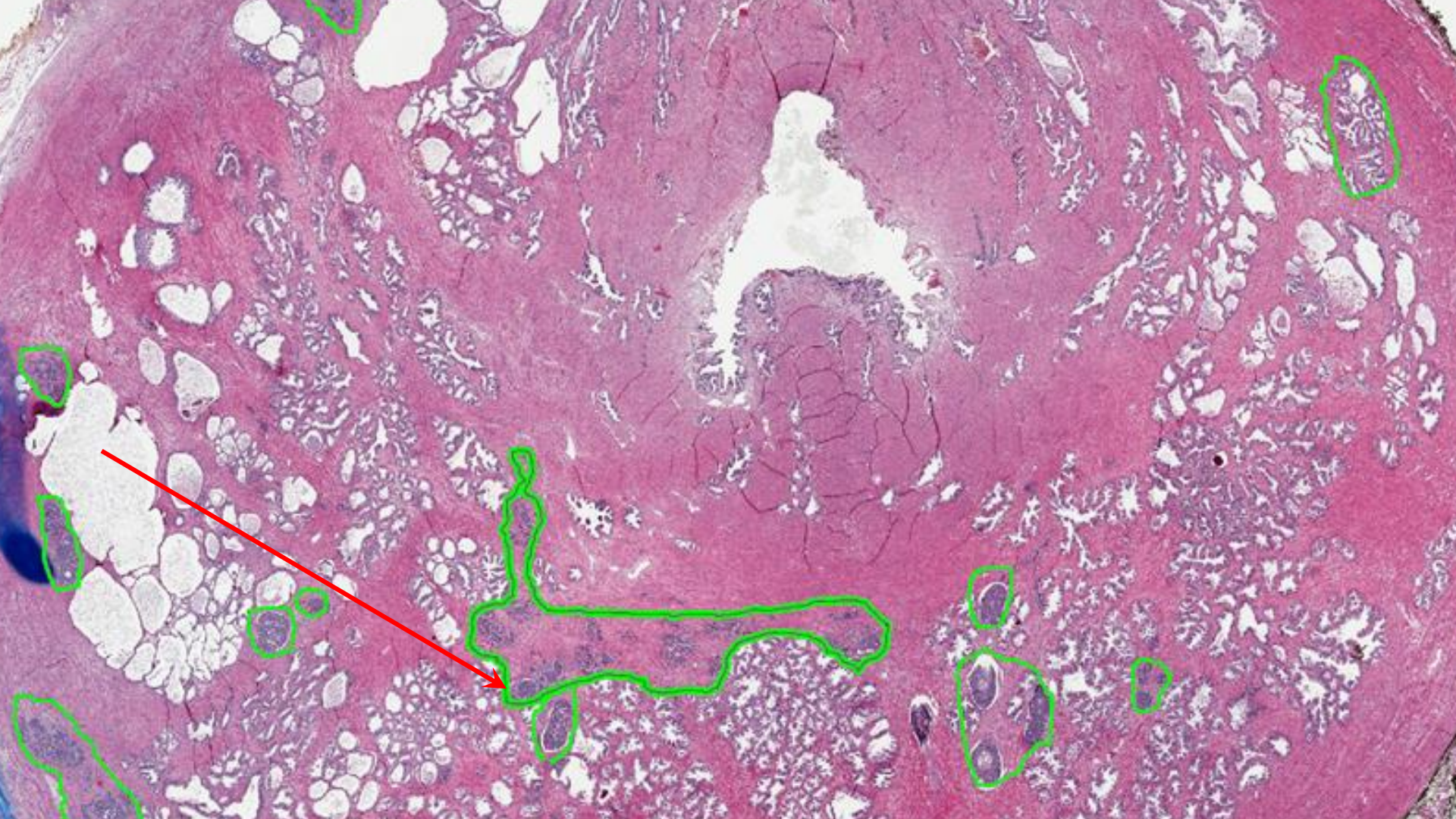
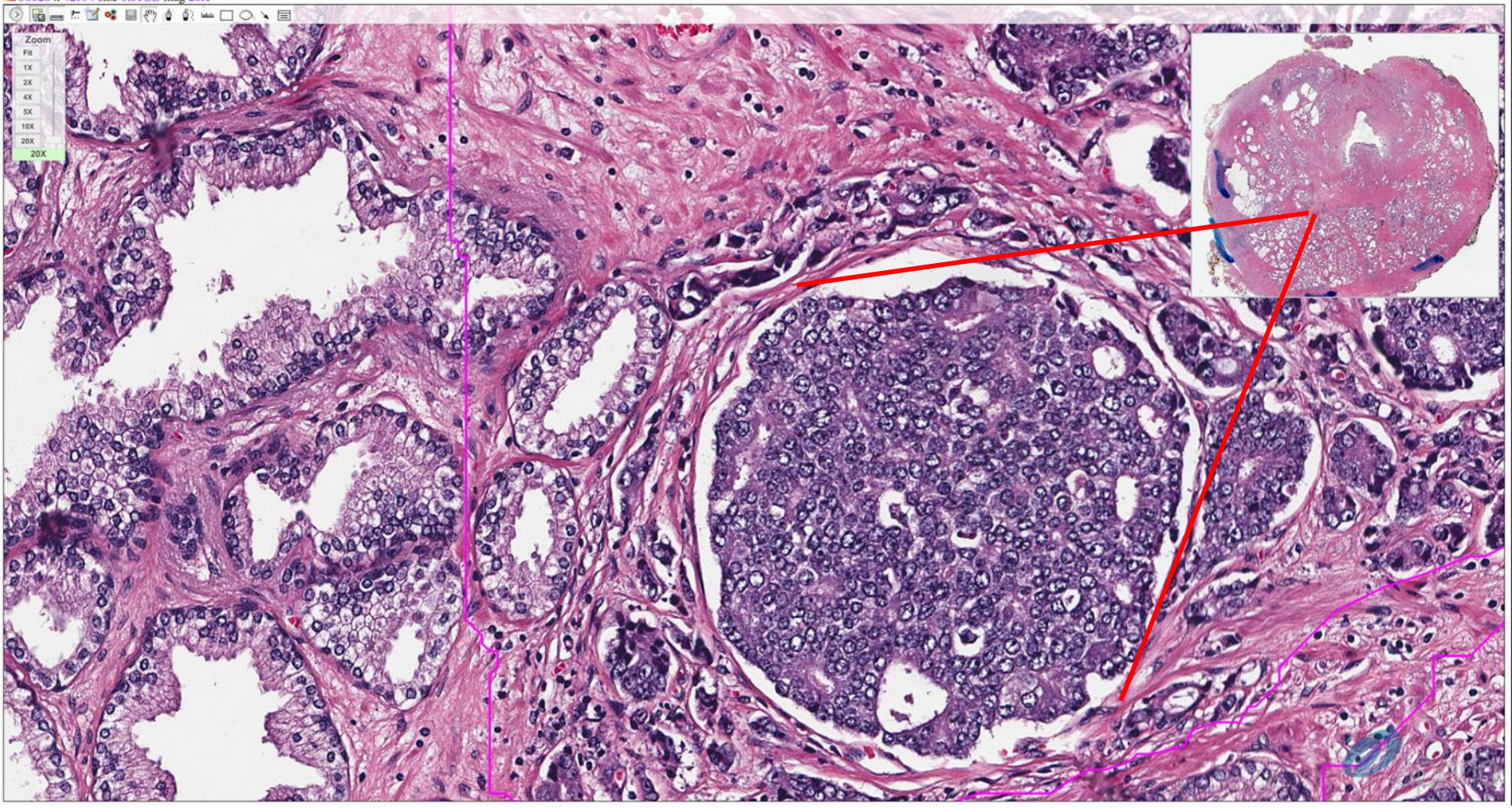
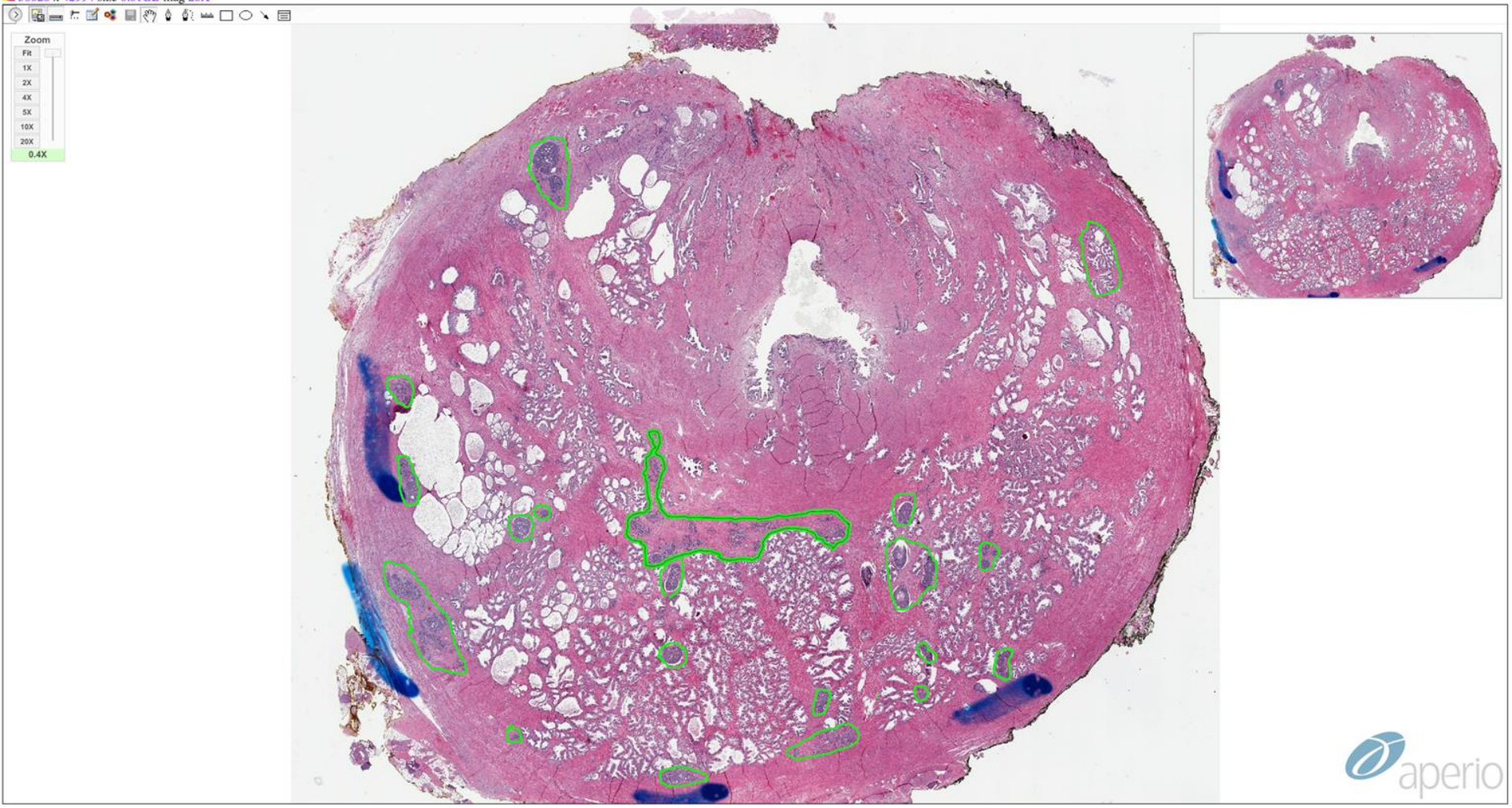
aperio



50028 x 42994 size 6.01GB mag 20X




Zoom
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20X
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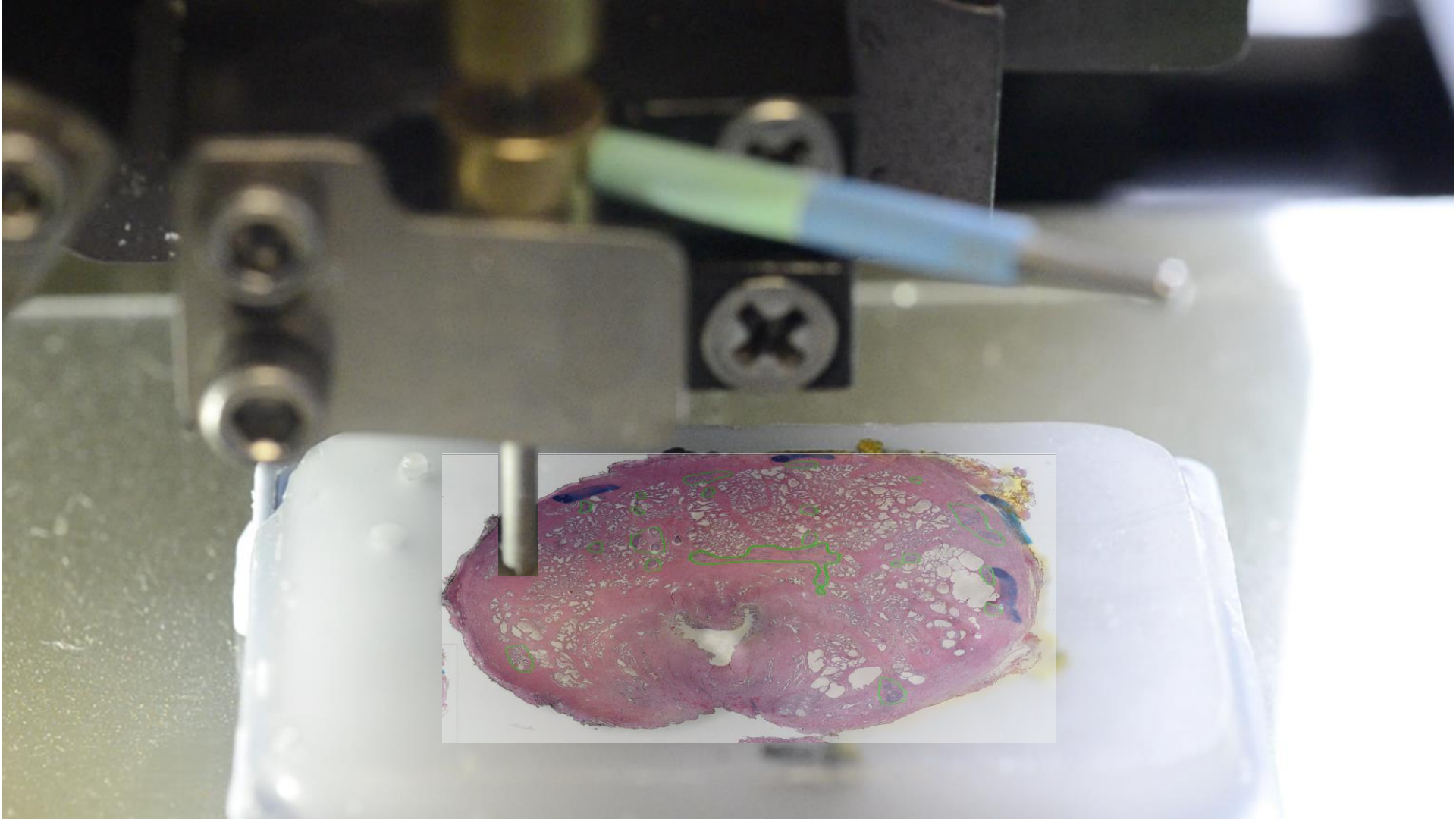
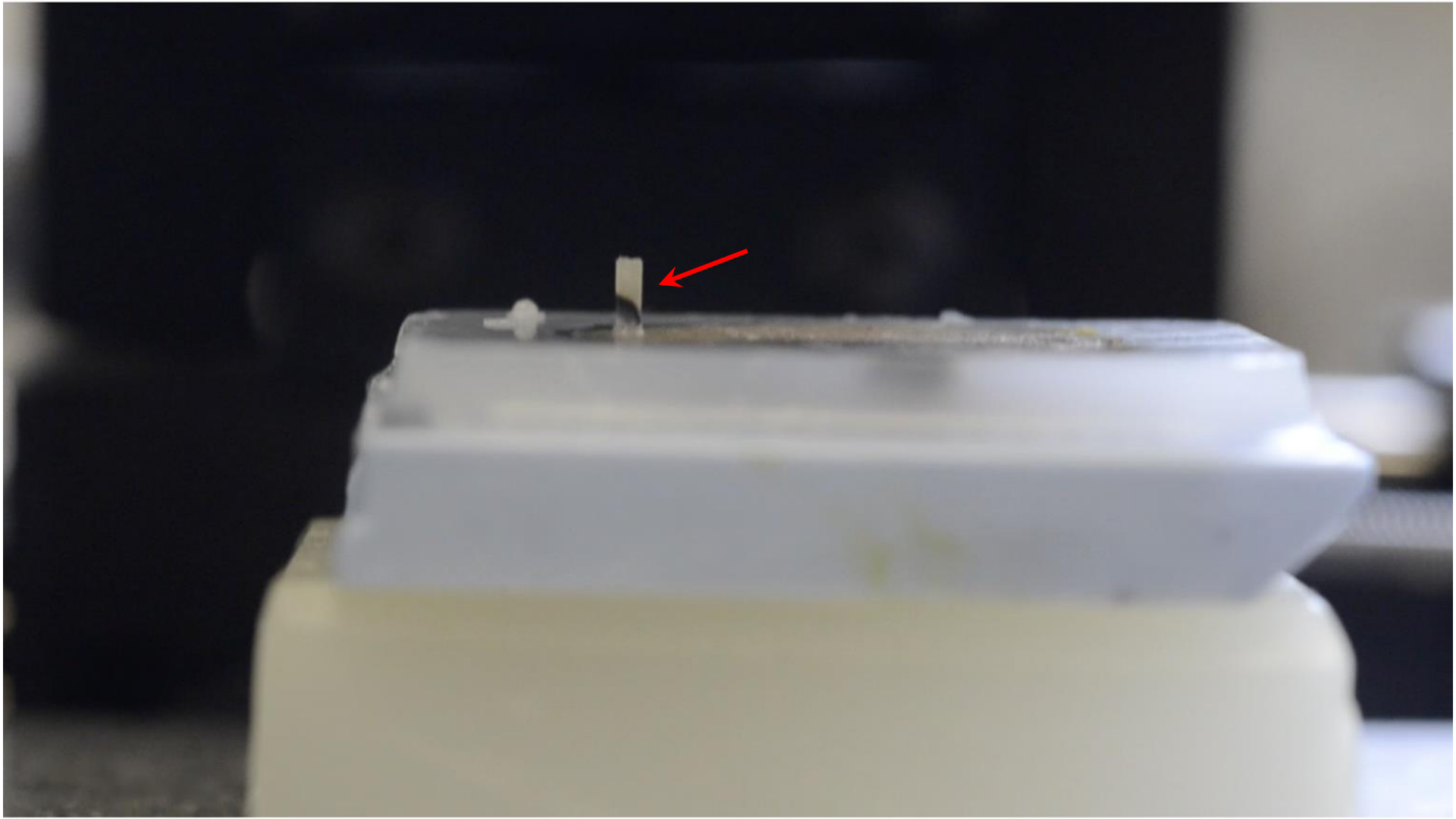
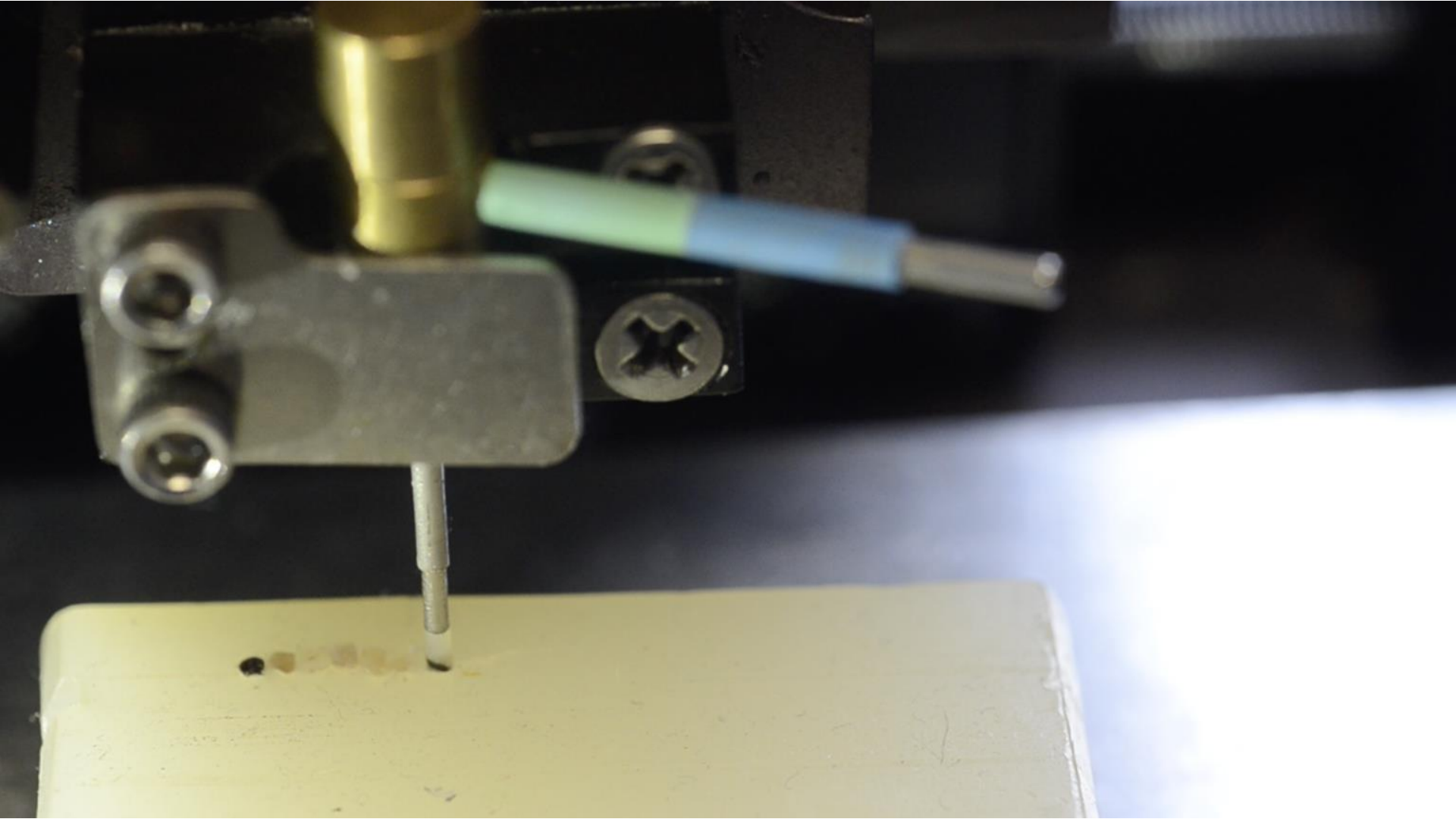
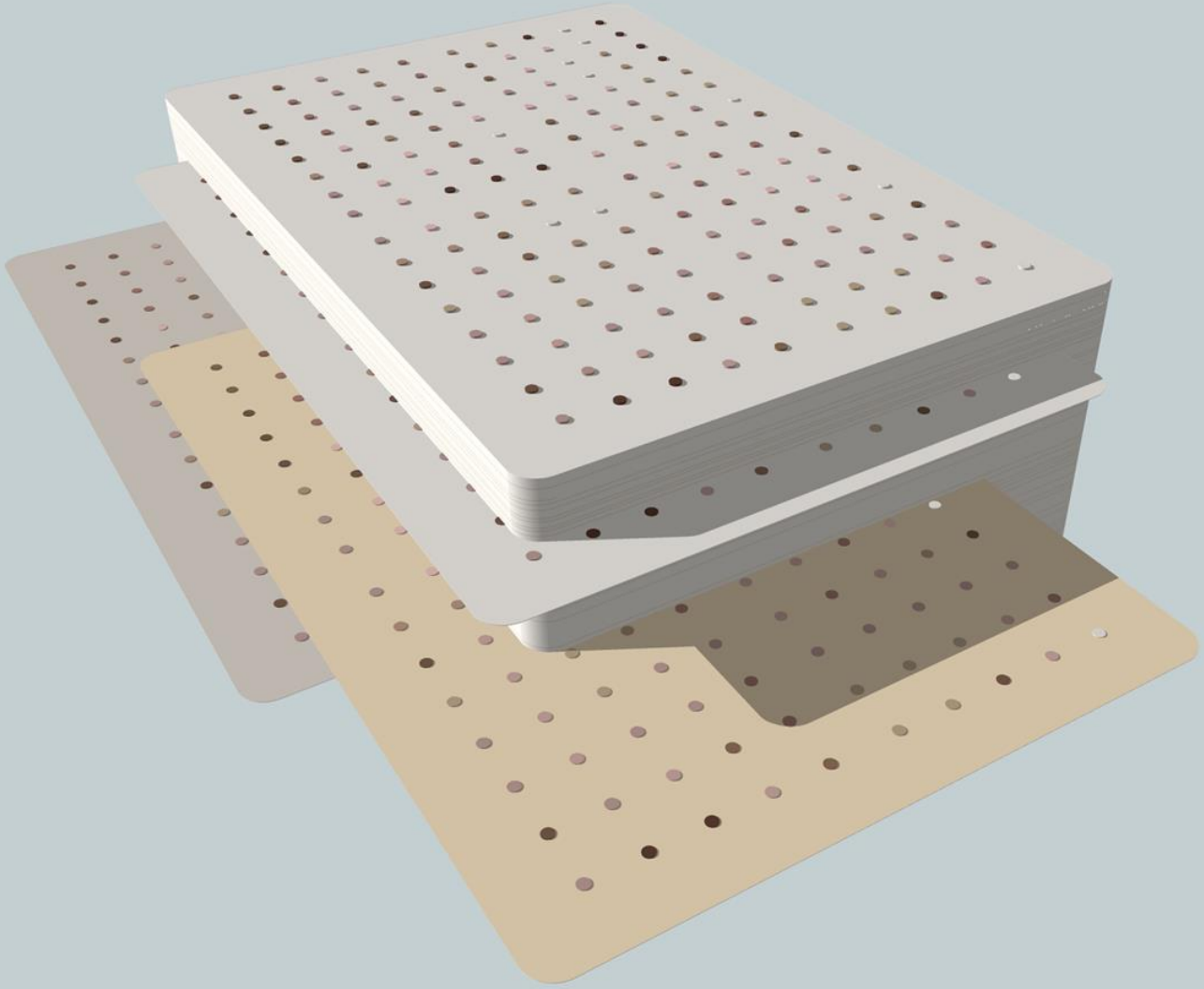
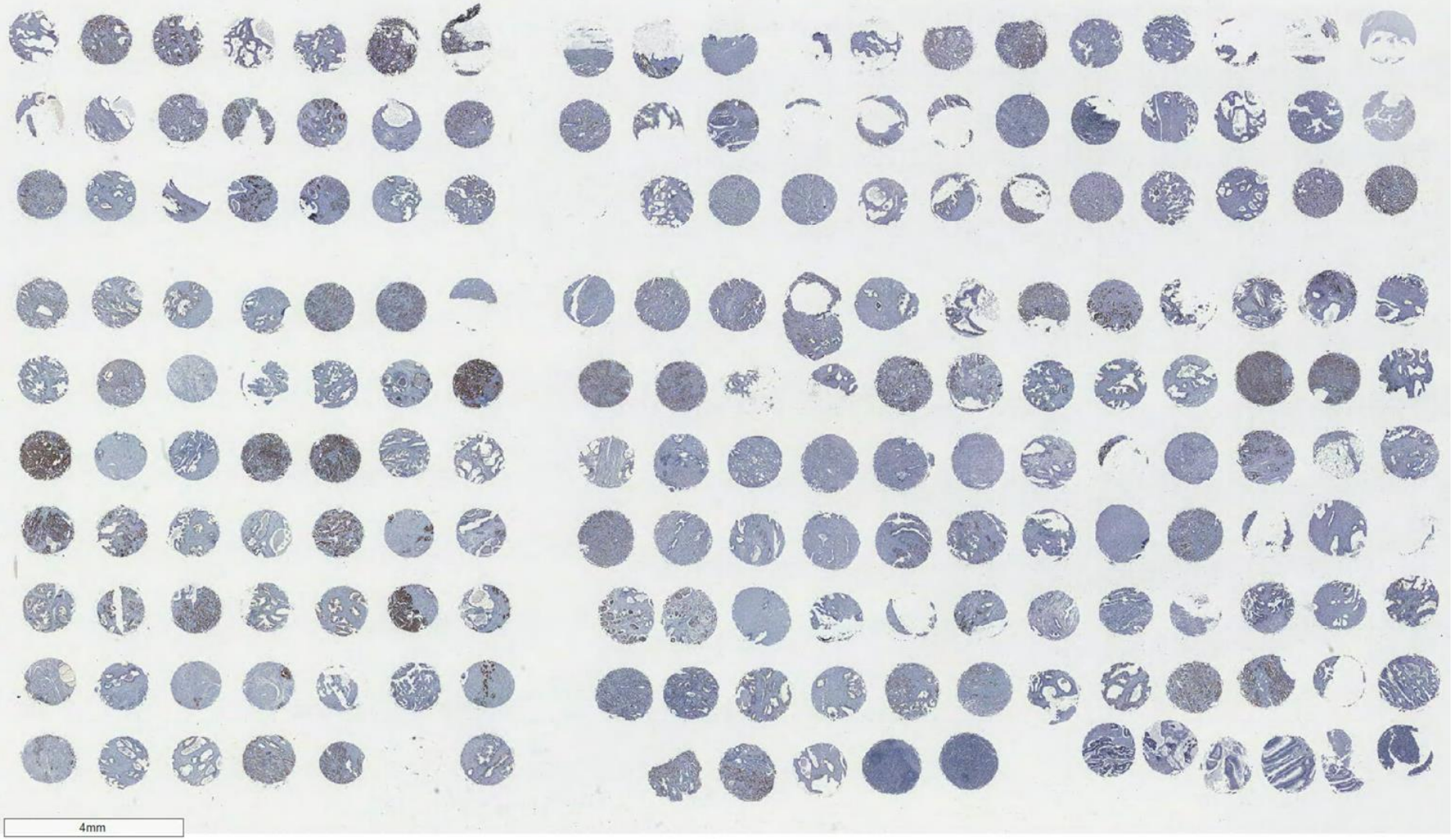


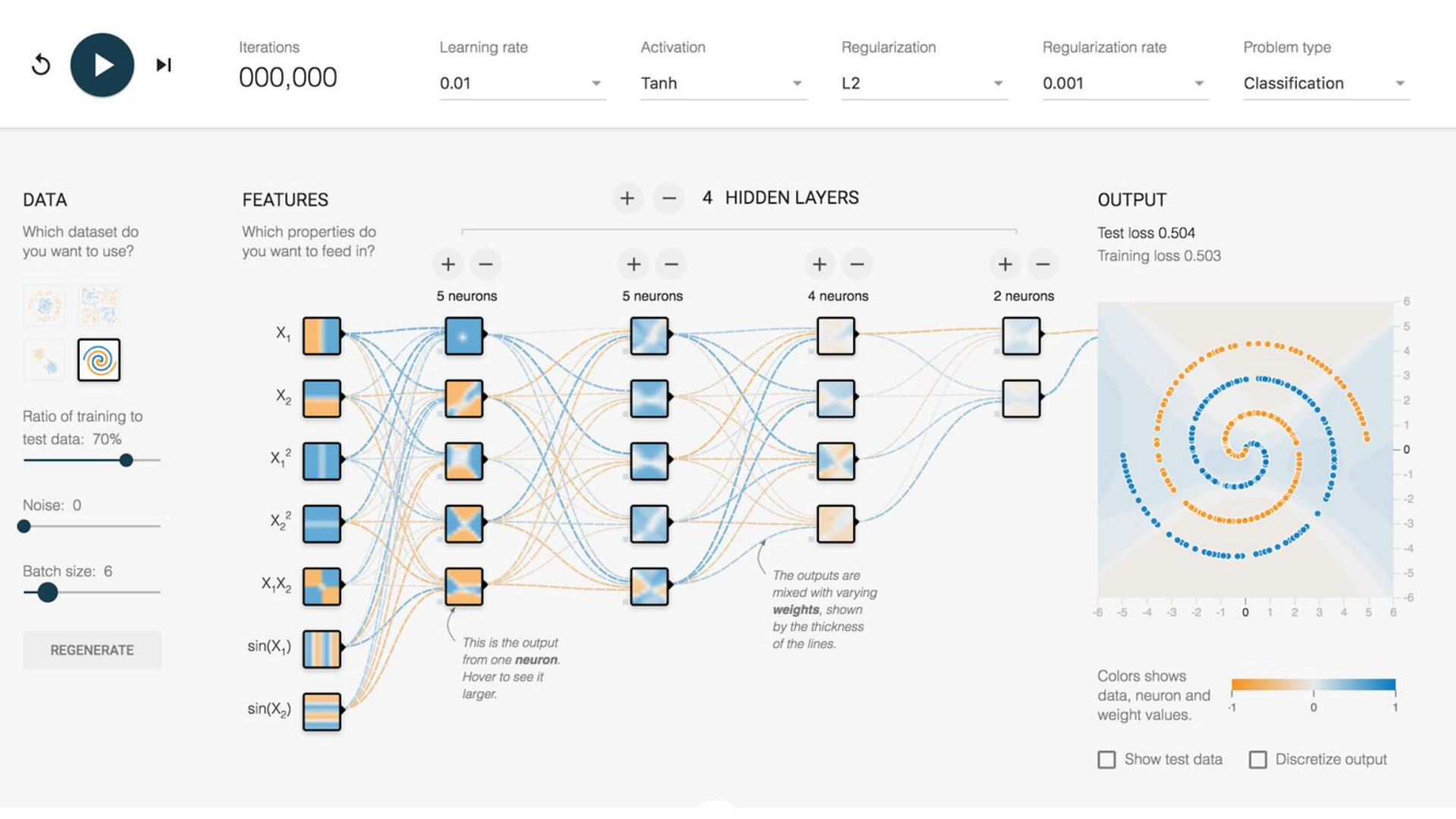


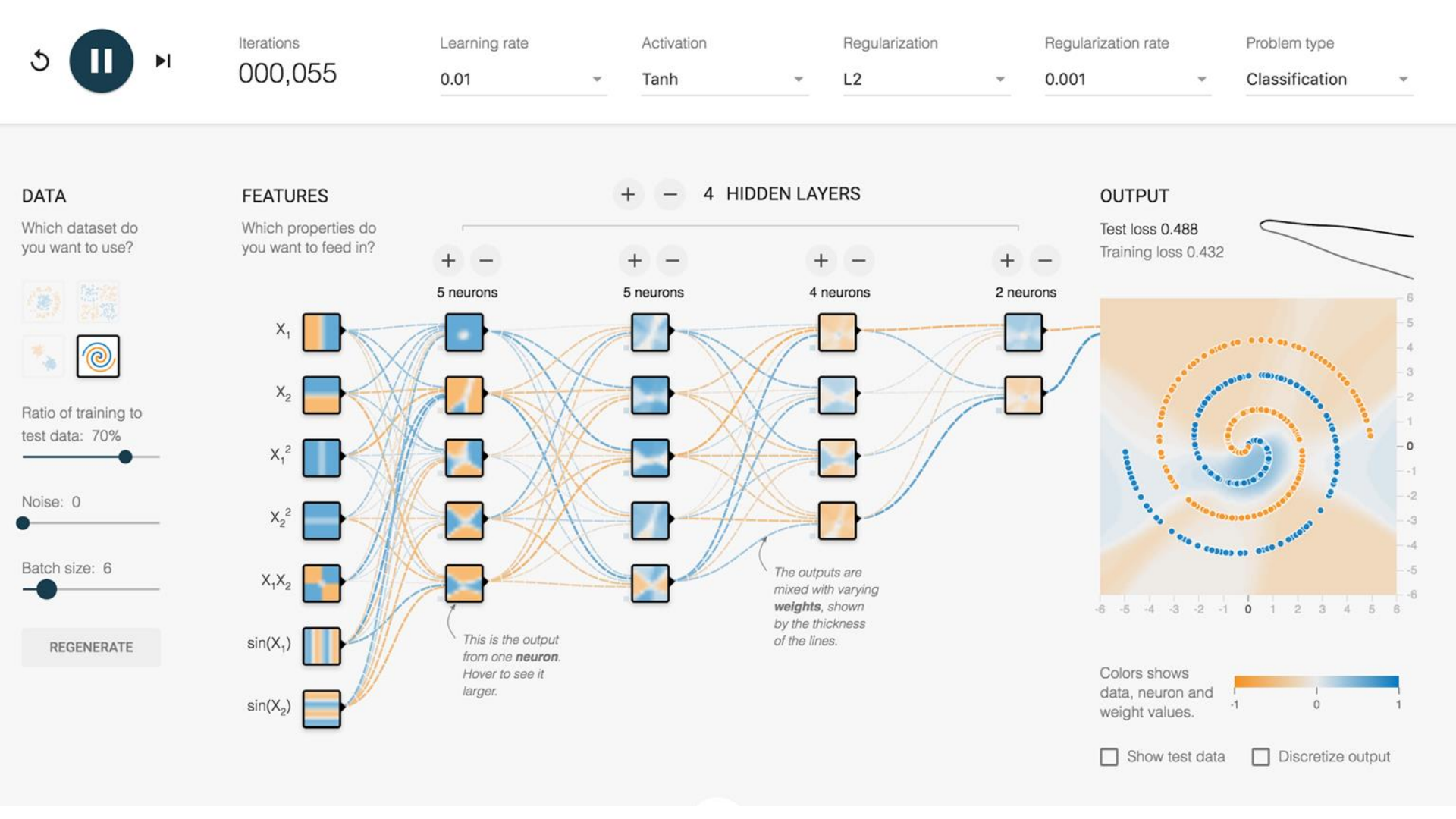





4mm

Teaching a Machine to Diagnose Cancer


Iterations
000,000
Learning rate
0.01
Activation
Tanh
Regularization
L2
Regularization rate
0.001
Problem type
Classification
DATA
Which dataset do you want to use?
Ratio of training to test data: 70%
Noise: 0
Batch size: 6
REGENERATE
FEATURES
Which properties do you want to feed in?
4 HIDDEN LAYERS
5 neurons
5 neurons
4 neurons
2 neurons
X1
X2
X1²
X2²
X1X2
sin(X1)
sin(X2)
This is the output from one neuron. Hover to see it larger.
The outputs are mixed with varying weights, shown by the thickness of the lines.
OUTPUT
Test loss 0.504
Training loss 0.503
Colors shows data, neuron and weight values.
-1
0
1
Show test data
Discretize output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X2
X1²
X2²
X1X2
sin(X1)
sin(X2)
This is the output from one neuron. Hover to see it larger.
The outputs are mixed with varying weights, shown by the thickness of the lines.
OUTPUT
Test loss 0.488
Training loss 0.432
Colors shows data, neuron and weight values.
-1
0
1
Show test data
Discretize output

Iterations
000,164

Learning rate: 0.01

Activation: Tanh

Regularization: L2

Regularization rate: 0.001

Problem type: Classification

DATA

Which dataset do you want to use?

Ratio of training to test data: 70%

Noise: 0

Batch size: 6

REGENERATE

FEATURES

Which properties do you want to feed in?

X_1

X_2

X_1^2

X_2^2

X_1X_2

$\sin(X_1)$

$\sin(X_2)$

4 HIDDEN LAYERS

5 neurons | 5 neurons | 4 neurons | 2 neurons

*This is the output from one **neuron**. Hover to see it larger.*

*The outputs are mixed with varying **weights**, shown by the thickness of the lines.*

OUTPUT

Test loss 0.235

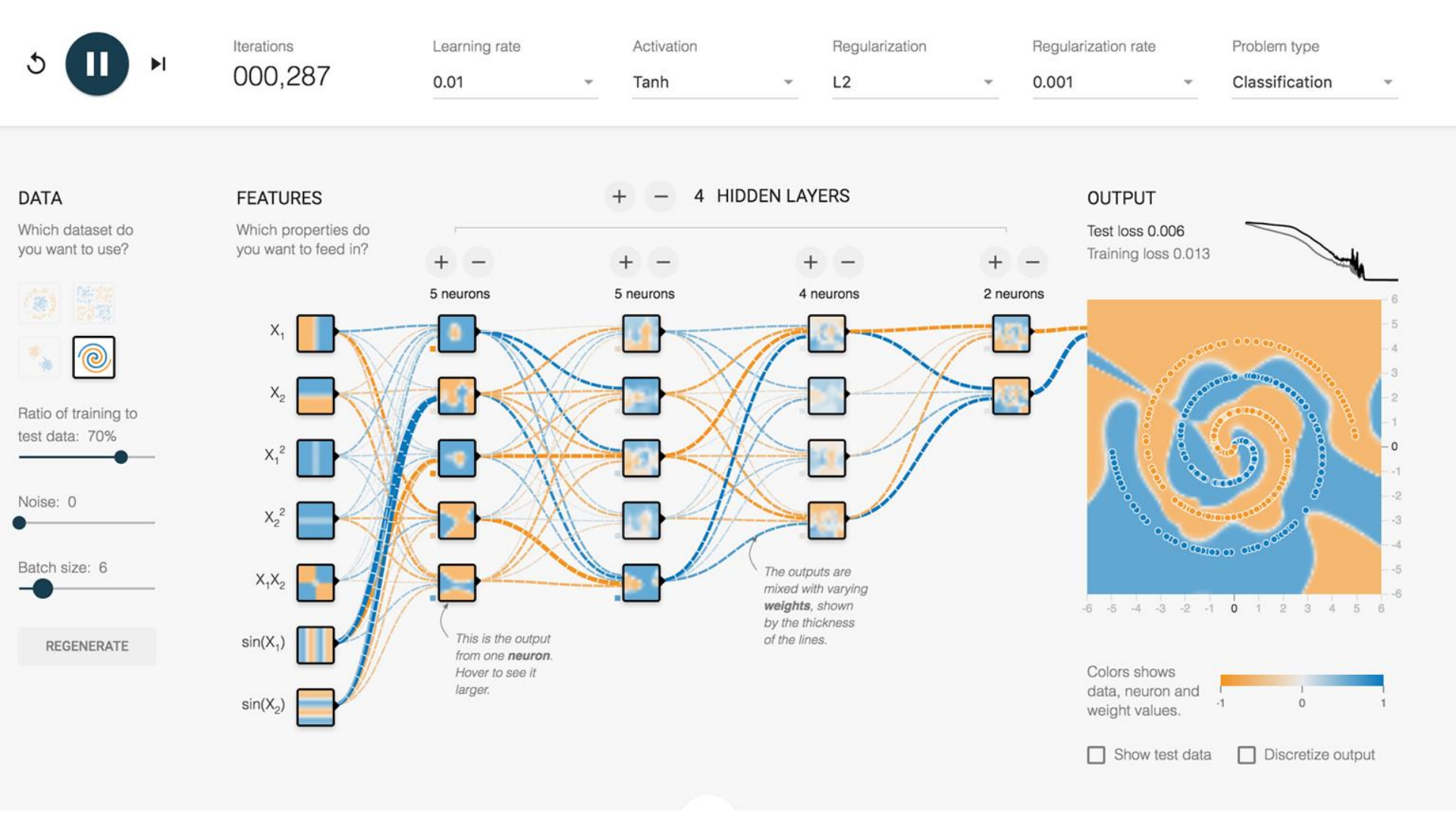
Training loss 0.174

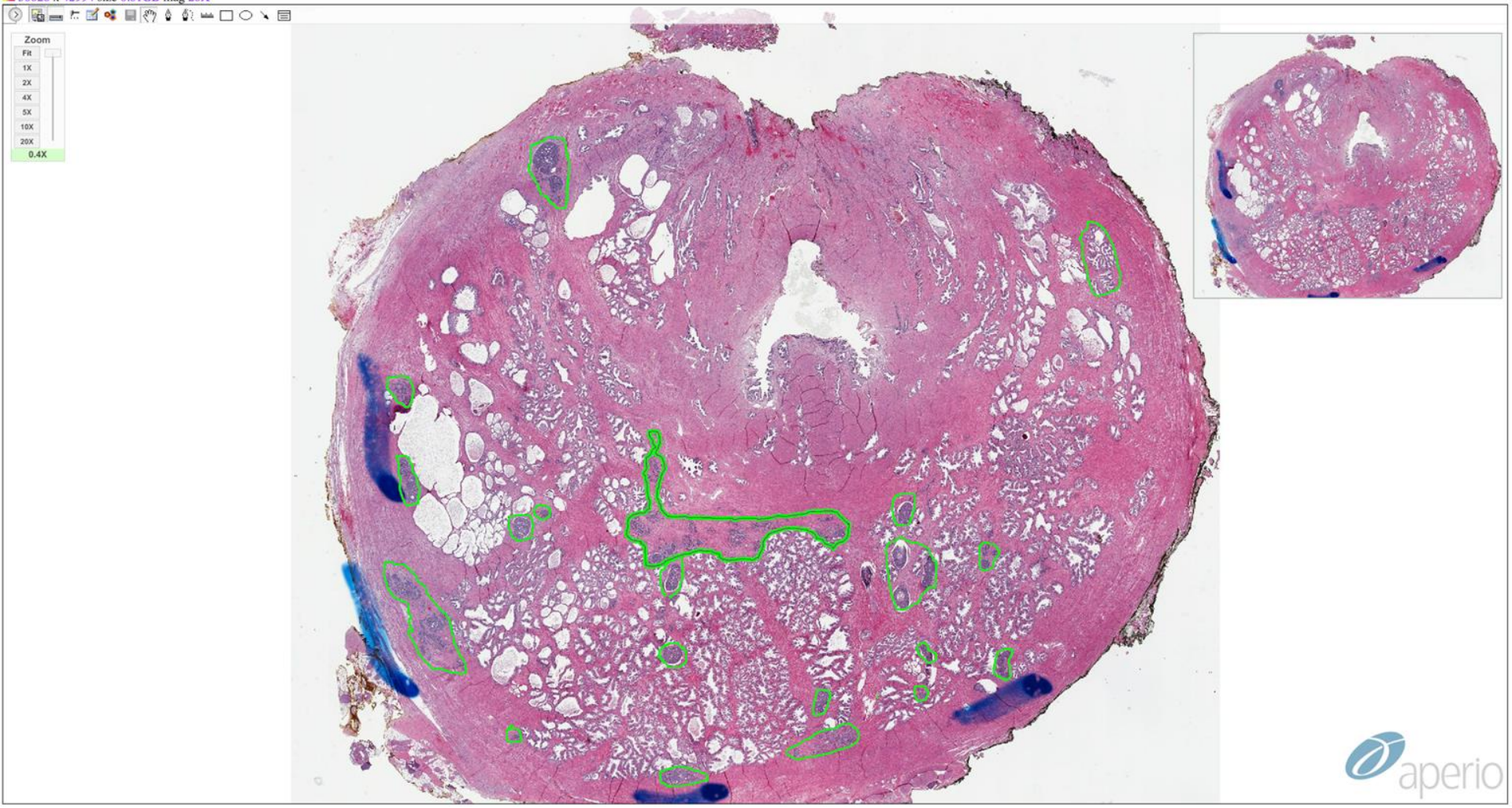
Colors shows data, neuron and weight values.

-1 0 1

Show test data

Discretize output


Iterations
000,287
Learning rate
0.01
Activation
Tanh
Regularization
L2
Regularization rate
0.001
Problem type
Classification
DATA
Which dataset do you want to use?
Ratio of training to test data: 70%
Noise: 0
Batch size: 6
REGENERATE
FEATURES
Which properties do you want to feed in?
4 HIDDEN LAYERS
5 neurons
5 neurons
4 neurons
2 neurons
X1
X2
X1²
X2²
X1X2
sin(X1)
sin(X2)
This is the output from one neuron. Hover to see it larger.
The outputs are mixed with varying weights, shown by the thickness of the lines.
OUTPUT
Test loss 0.006
Training loss 0.013
Colors shows data, neuron and weight values.
-1
0
1
Show test data
Discretize output


Zoom
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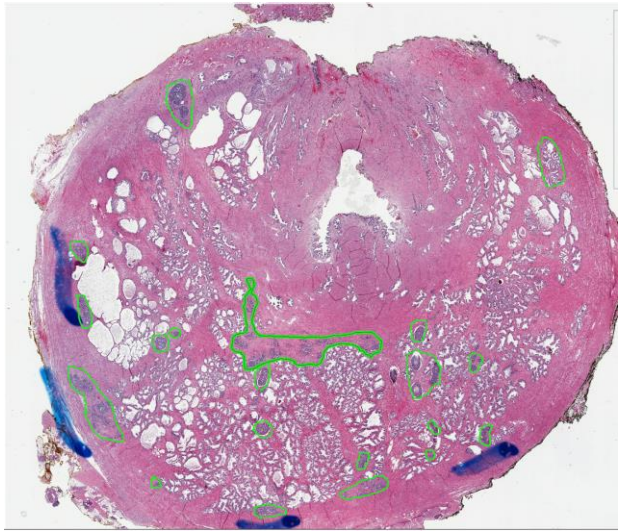
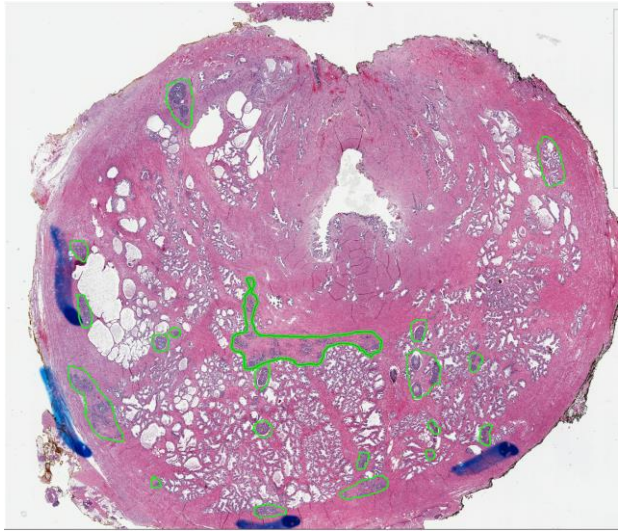
aperio


GTX980
NVIDIA

NAVAL MEDICAL CENTER
SAN DIEGO



Methods and Materials



Data

- 202 annotated color Aperio SVS images
- Scanned with an Aperio CS-1 at 20x
- 106,024 image chips at 10x magnification
- Average full size image ~ 845 MB
- Annotated by Navy pathologists
- Manually specifying additional categories: ink, white space, fat, and stroma

System

- NVIDIA GeForce GTX980 GPU (single card) via Intel Haswell-E PCIe 3.0
- Maxwell architecture, 2048 CUDA cores, 4GB memory, NV driver 352.63
- 6-core Intel Xeon E5-2603 v3 at 1.60 GHz with 16GB DDR4
- Ubuntu 14.04, DIGITS 3.0-rc3, CUDA 7.5, cuDNN v4, NVCaffe 0.14

Results

March 2016

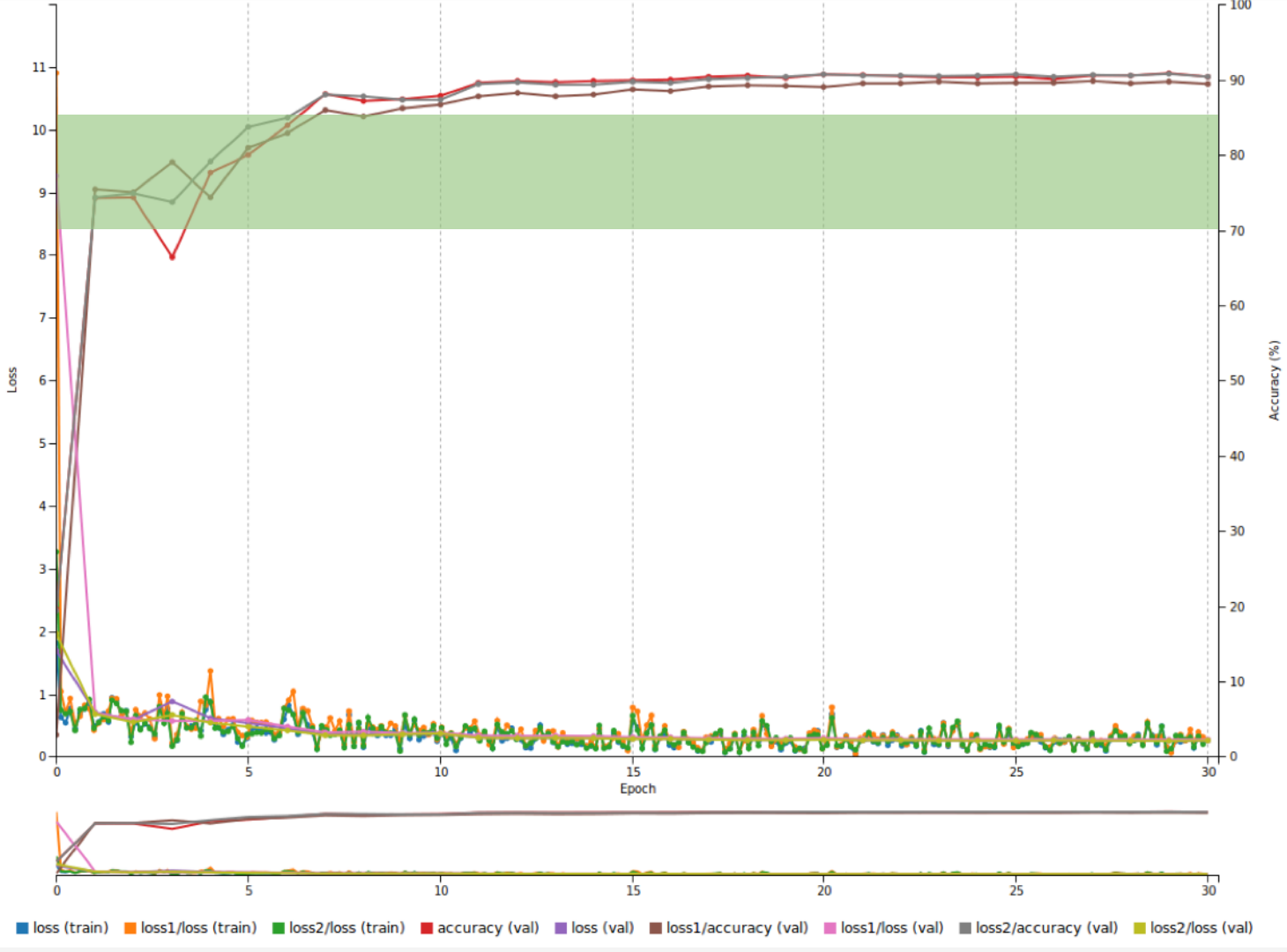
256x256

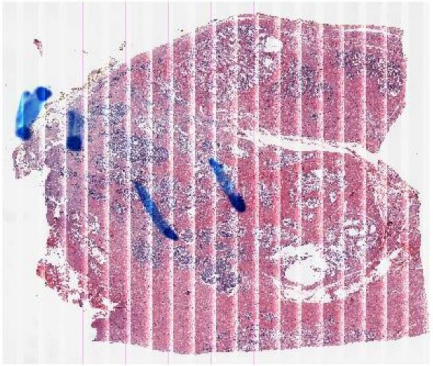
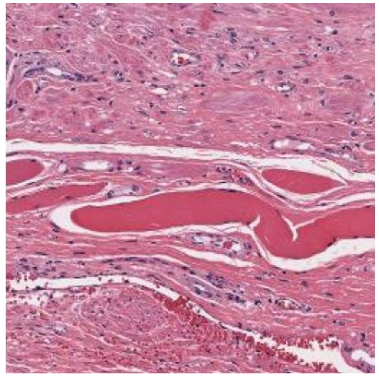
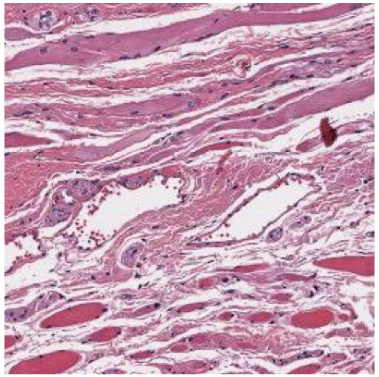
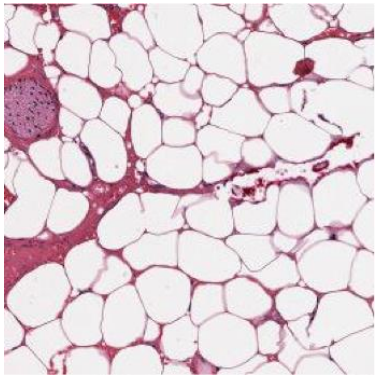
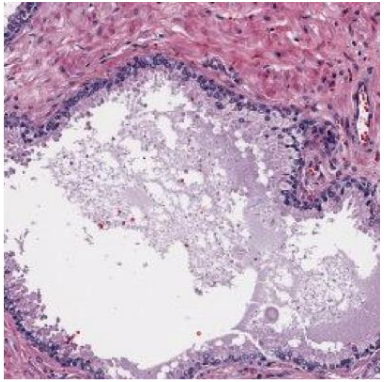
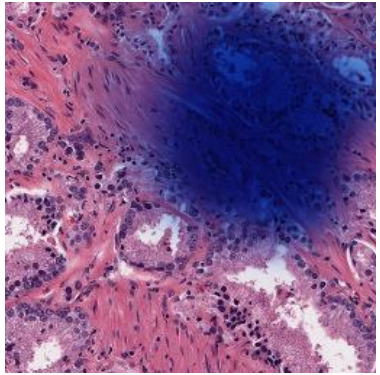
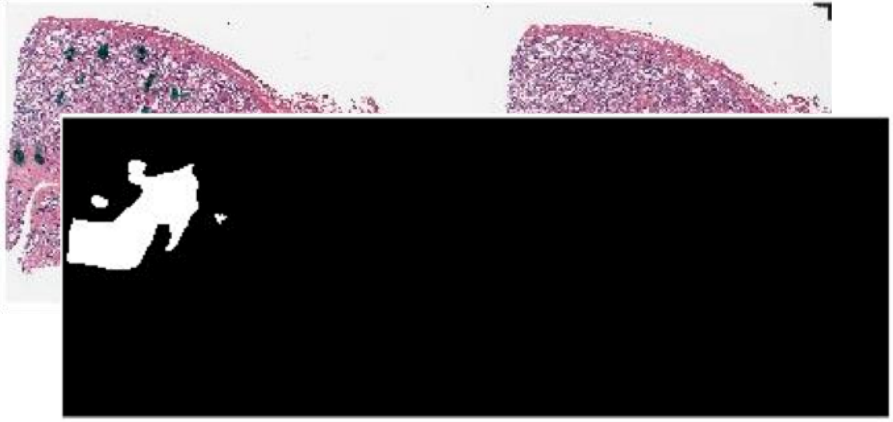
Full color

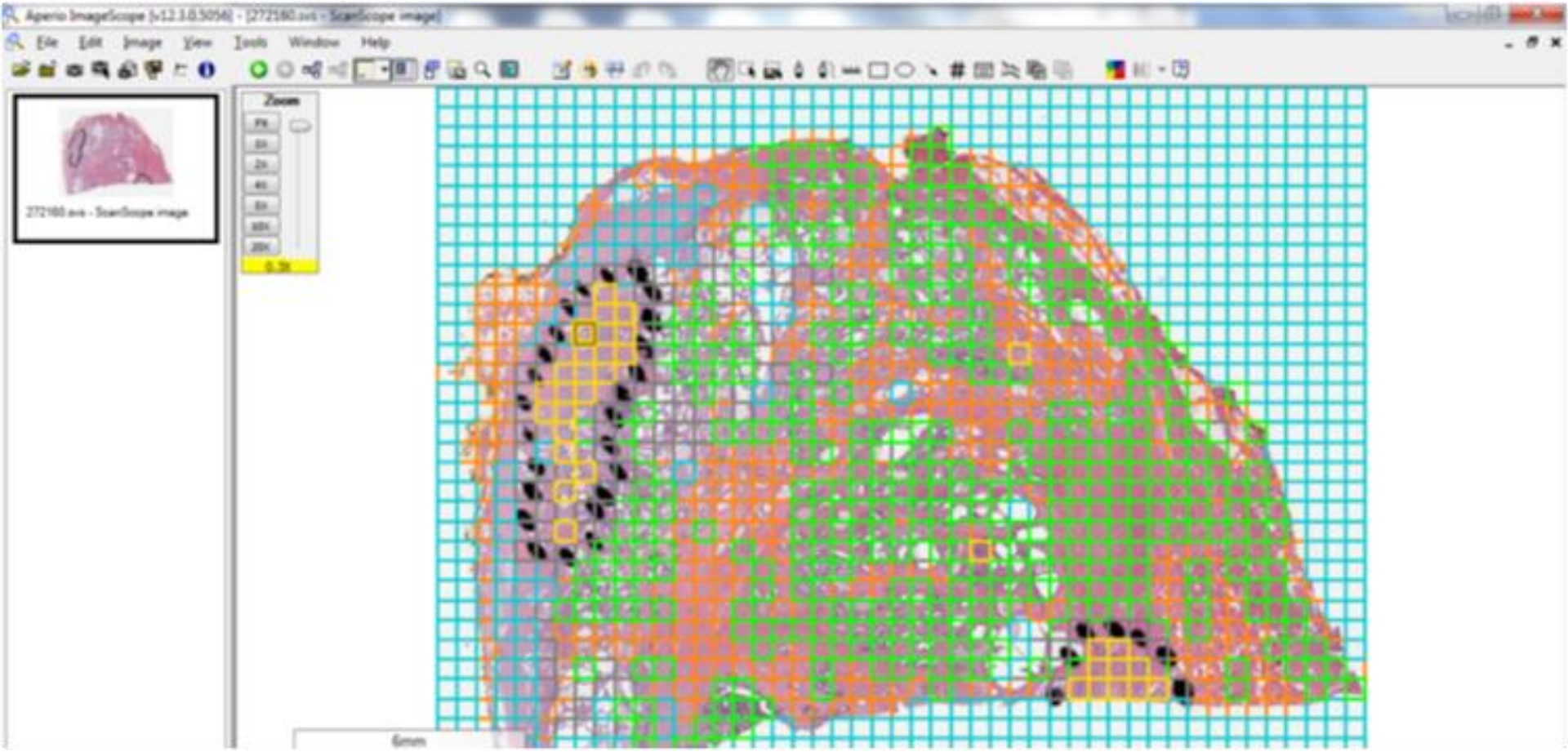
GoogLeNet

60 epochs

Additional annotation of previously unrelated image contents (fat, surgical ink, marking ink).



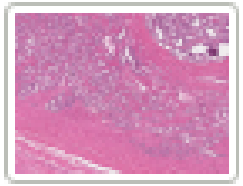









Aperio ImageScope
File
Edit
Image
View
Tools
Window
Help
Zoom
272160.svs - ScanScope image
6mm


3_orig.jpg


3_pred.jpg


3_true.jpg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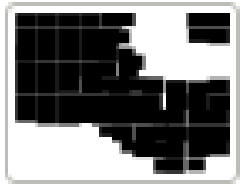
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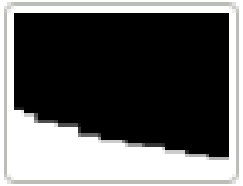
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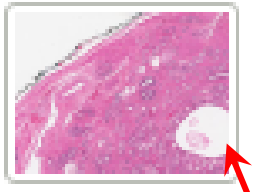
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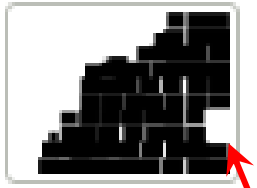
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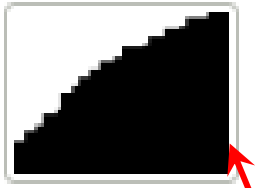
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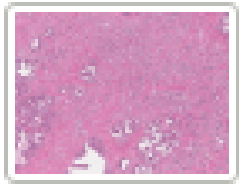
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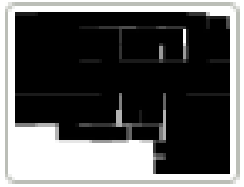
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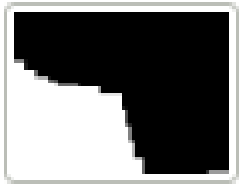
9_true.jpg

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Submitted: 05:21:27 PM
Status: Done after 31 seconds
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Status: Done after 2 minutes, 26 seconds
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New Model
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Status: Running
Completed
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GEFORCE GTX
GEFORCE GTX
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SPAWAR

Systems Center PACIFIC

HPC Modernization Program

DREN

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