

PathAI: Artificial Intelligence for Pathology

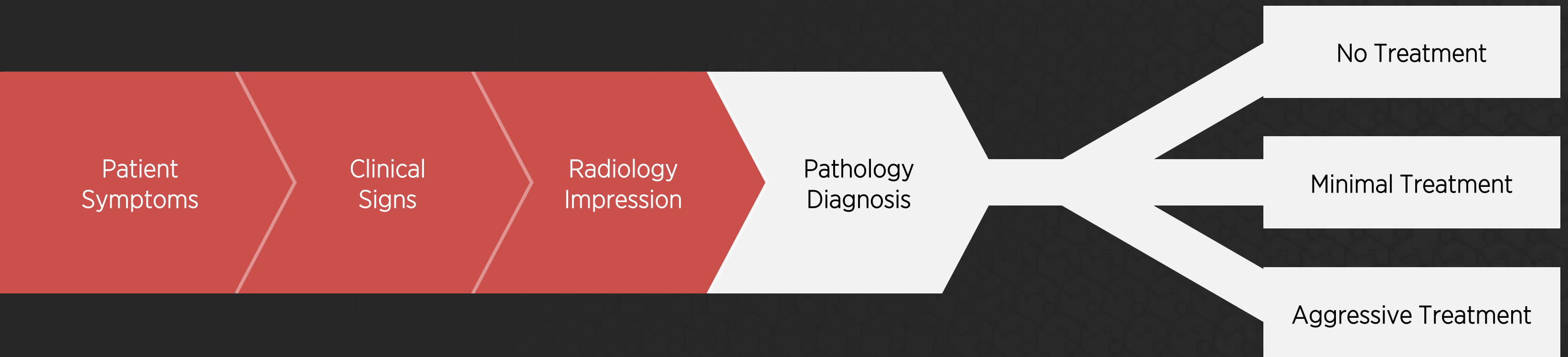
PRISME Forum Technical Meeting

Data-readiness in a world of AI

November 15, 2018

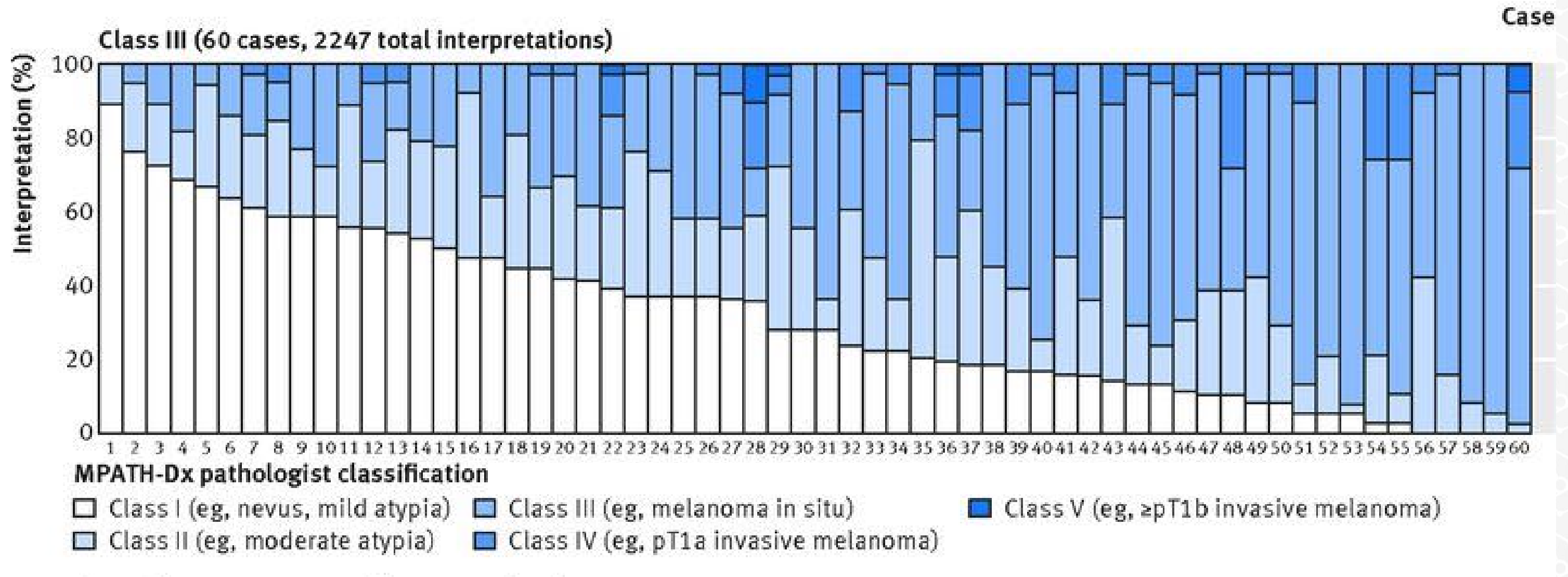
Chicago, IL

Pathology is medicine's ground truth



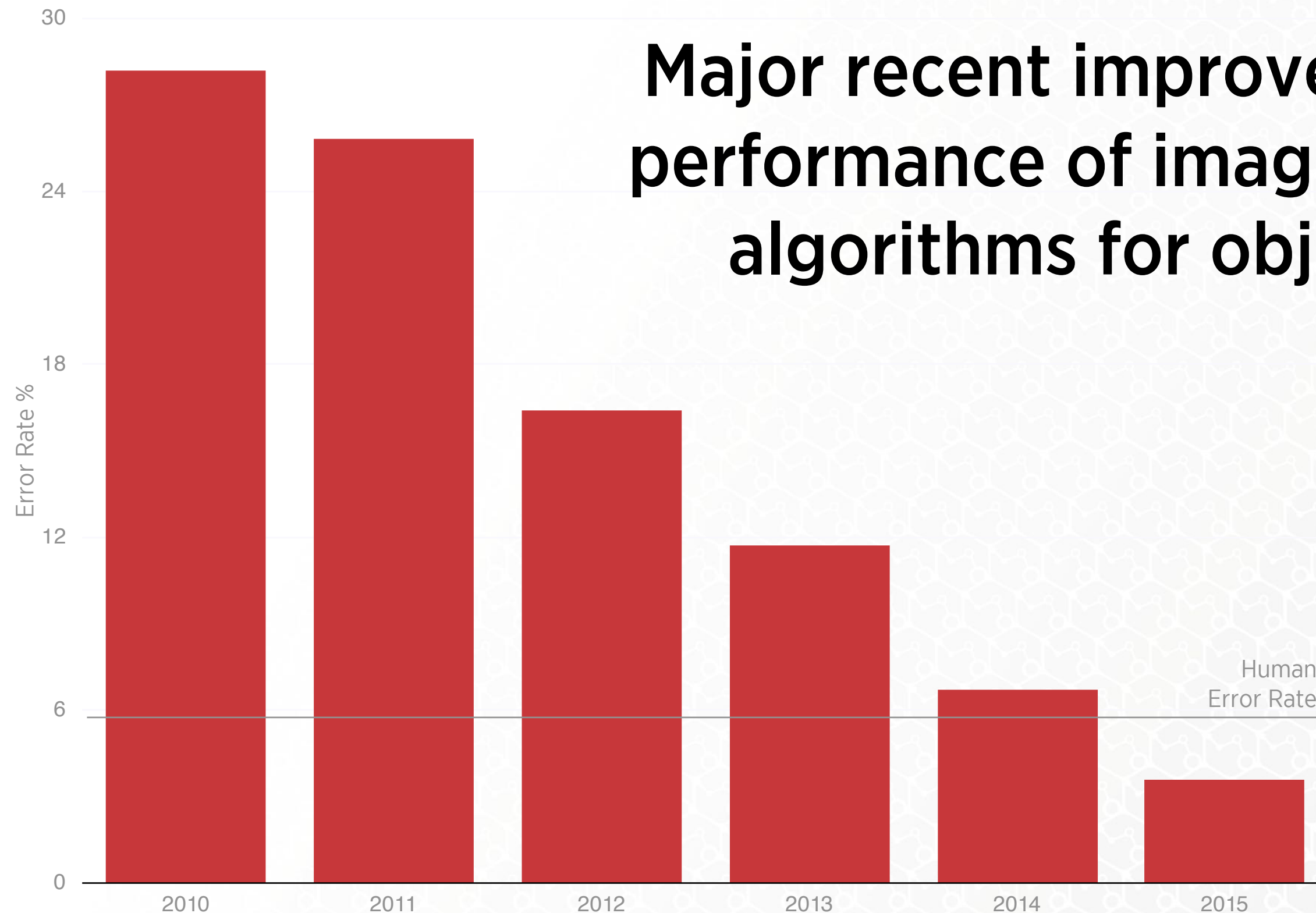
Pathologic diagnosis informs all subsequent medical decisions

Discordance among pathologists is common



- 187 pathologists interpreted skin lesion biopsies, resulting in an overall discordance of 45%
- 118 pathologists read the same samples 8 months apart, and had an intraobserver discordance of 33%

Major recent improvements in the performance of image recognition algorithms for object detection

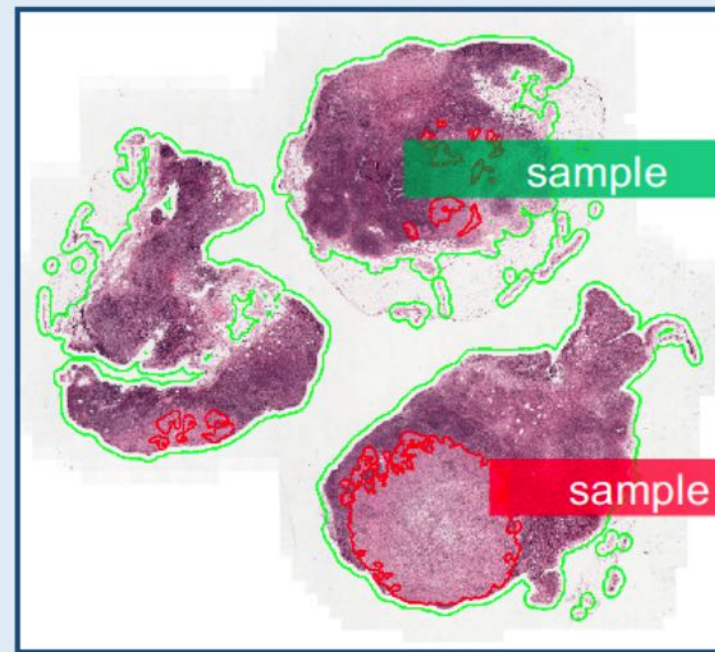


ImageNet Performance over Time

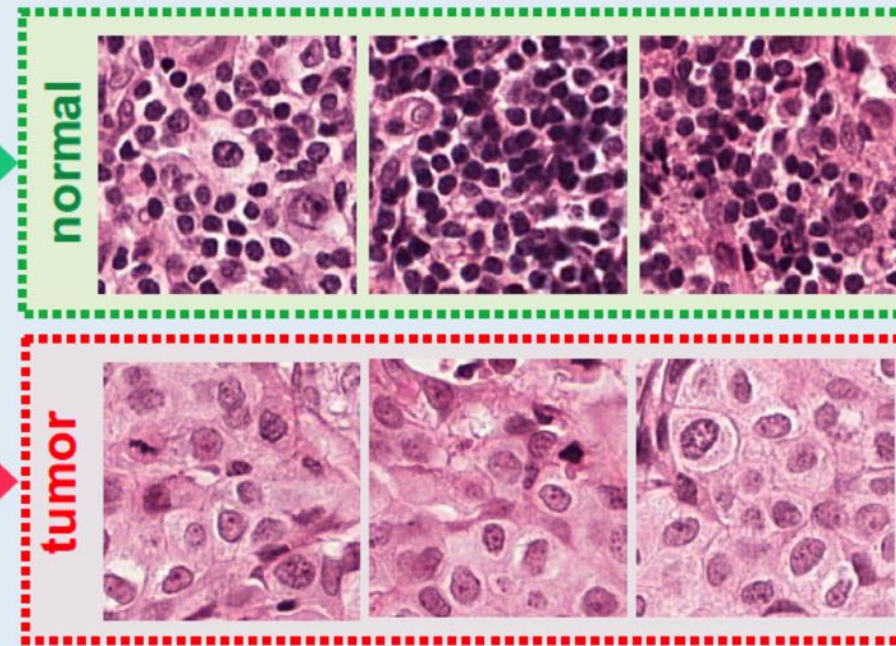
Deep Learning for Pathology

Wang, Khosla, ... Beck (2016) <https://arxiv.org/abs/1606.05718>

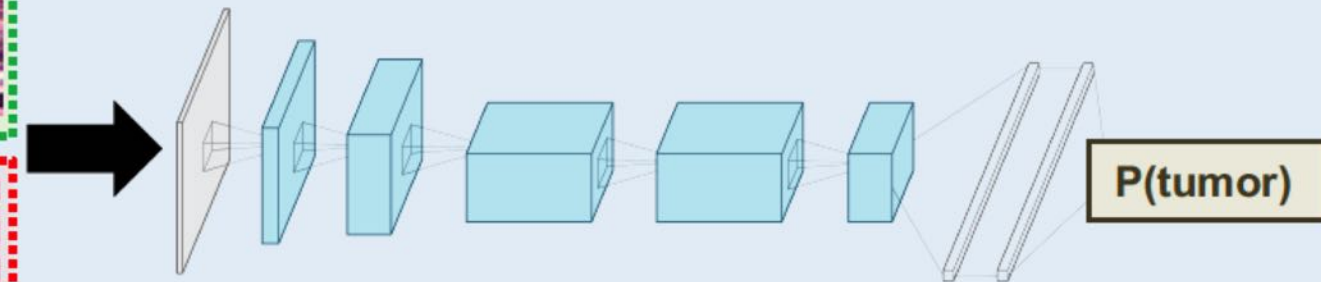
Train



whole slide image



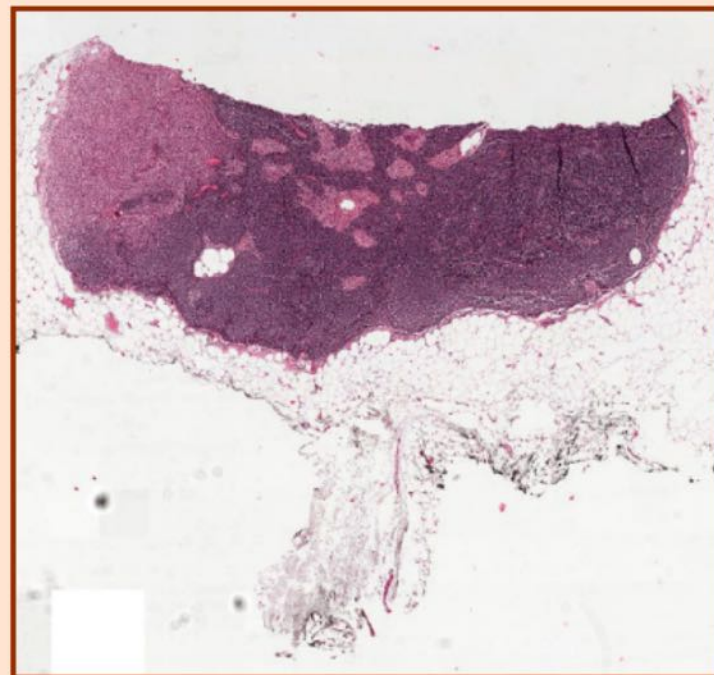
training data



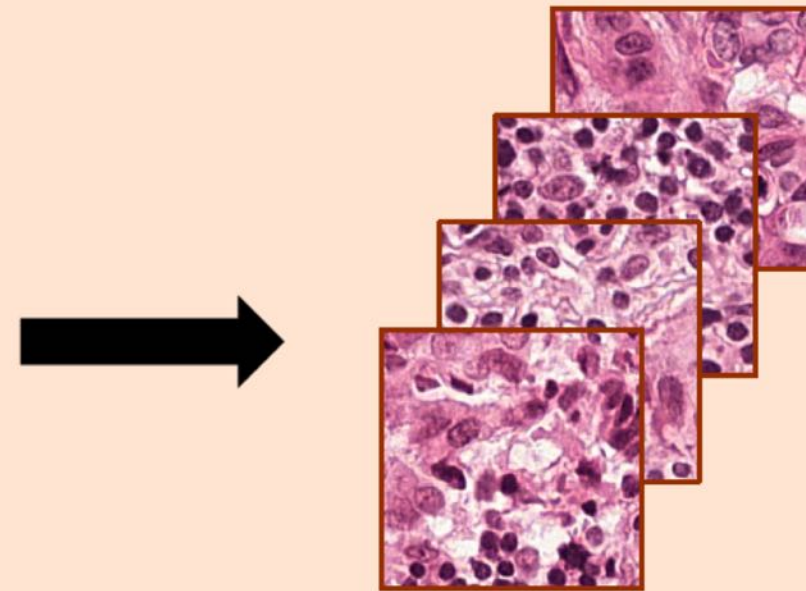
deep model

$P(\text{tumor})$

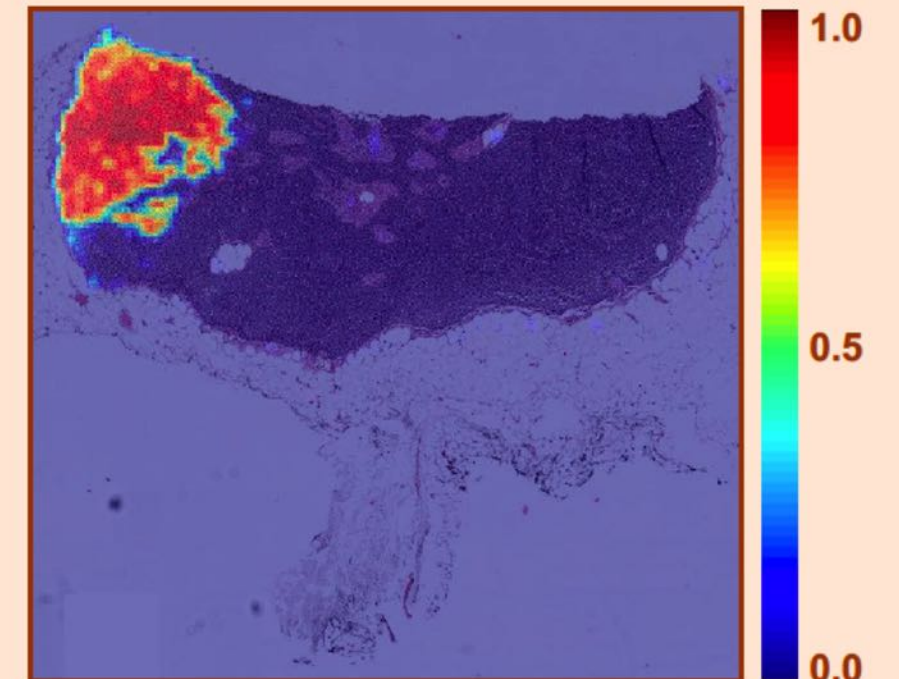
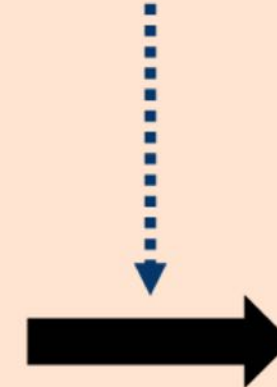
Test



whole slide image



overlapping image patches



tumor prob. map

Deep learning model outperforms human pathologists in the diagnosis of metastatic cancer

Error Rate

Pathologists in competition

3.5%



Pathologists in clinical practice¹

13 – 26%



Pathologists on micro-metastasis²

23 – 42%



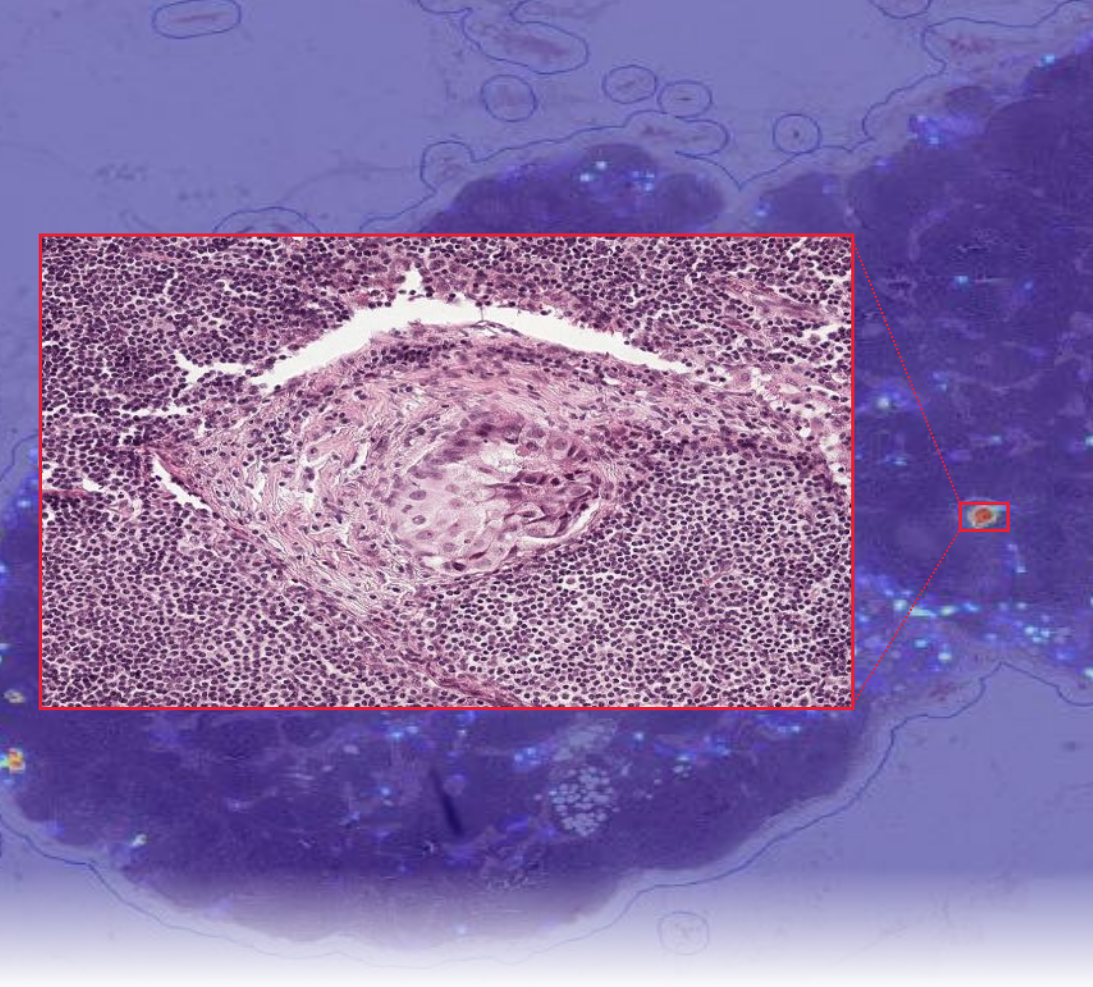
Deep learning model

0.65%

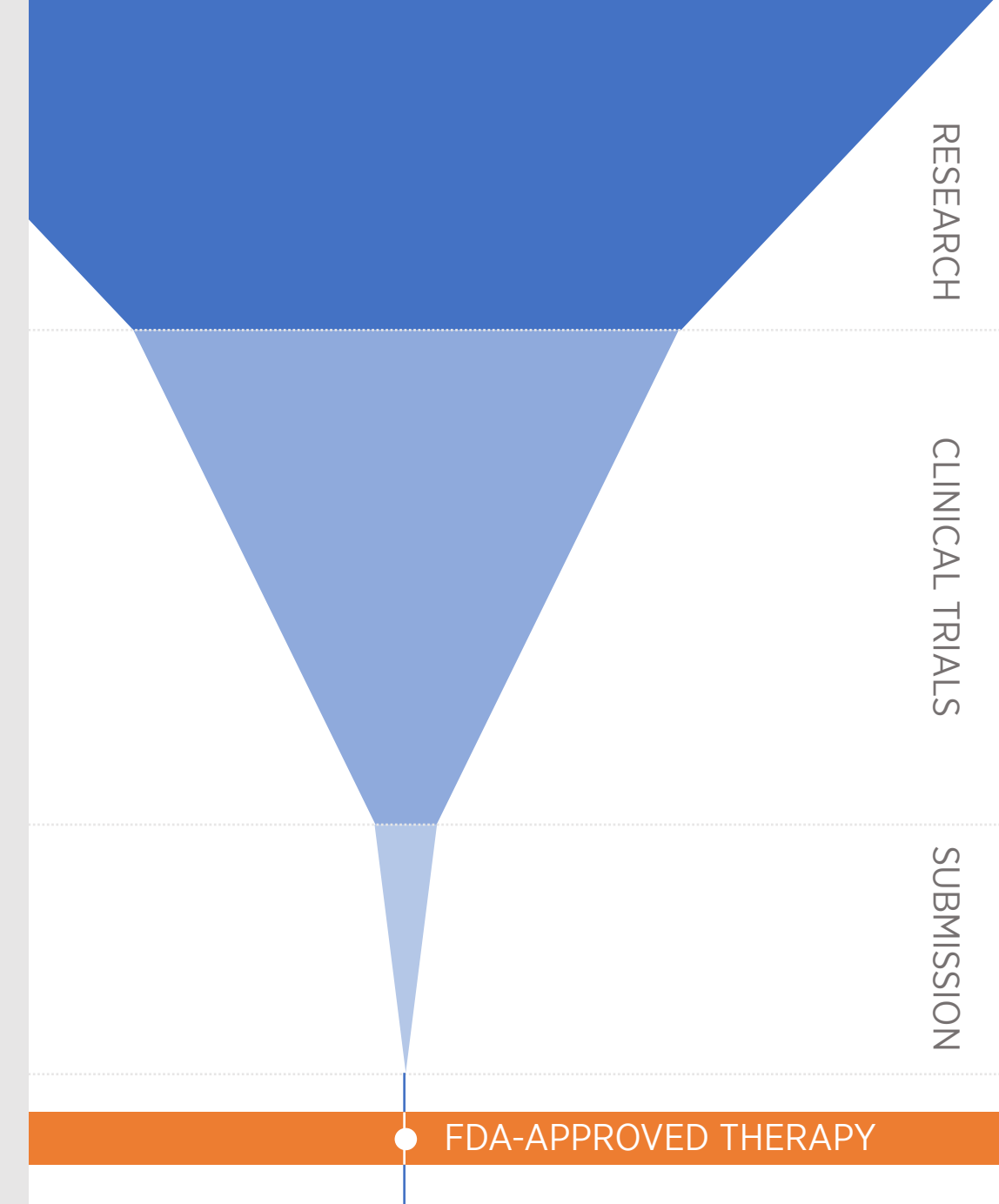
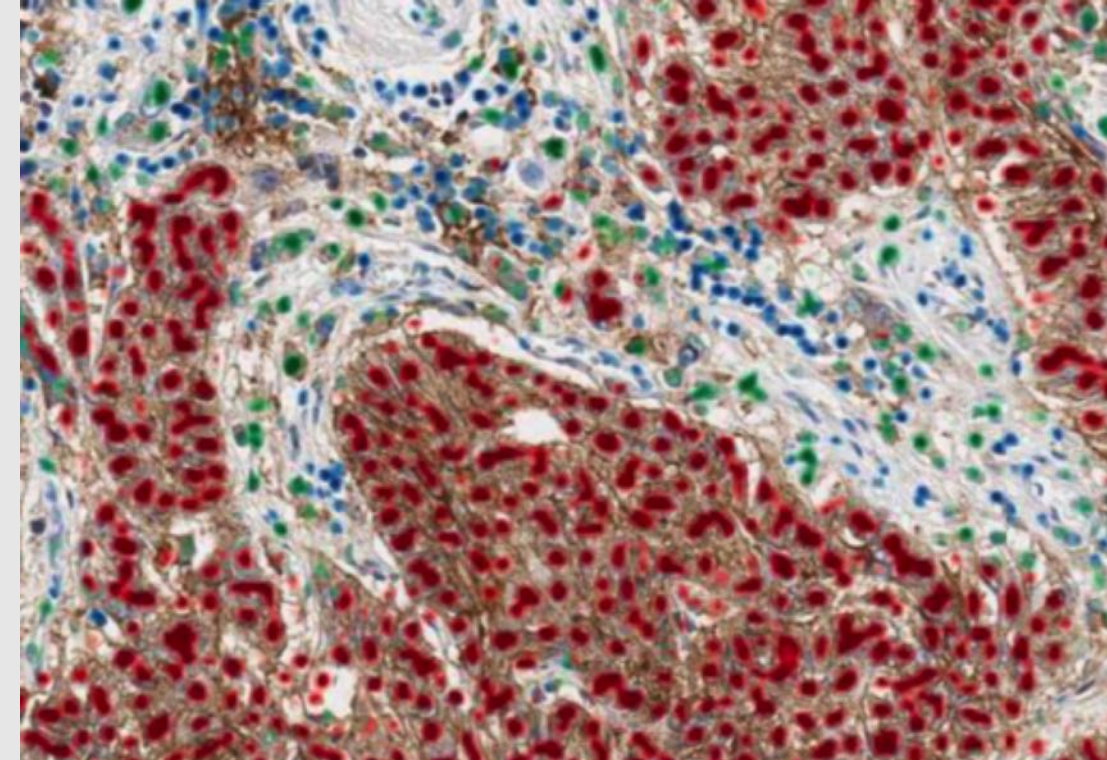


¹n=12

² Small tumors



| Error Rate | |
|--|----------|
| Pathologists on micro-metastasis ² | 23 – 42% |
| Pathologists in clinical practice ¹ | 13 – 26% |
| Pathologists in competition | 3.5% |
| PathAI deep learning model | 0.65% |



PathAI Platform & Company Timeline

2016

PathAI founded by Andy Beck & Aditya Khosla, built leading AI-powered diagnostic application for metastatic breast cancer.

2017

PathAI partners with major pharma companies & discovers novel pathologic signatures of IO drug response. Raises \$11M Series A led by General Catalyst. 15 Employees

2018

Expanding across major disease areas & biomarkers to provide AI-powered pathologic insights & CDx. 45 Employees



Andrew Beck MD, PhD

Co-Founder & CEO

- PhD, Biomedical Informatics (Stanford), MD (Brown), BS (Brown)
- Built the first machine learning-based computational pathology system. Published over 120 papers and supported by over 20 grants.
- Harvard Medical School faculty 2011-2017 as Associate Professor before founding PathAI



Jeffrey Leiden MD, PhD

Chairman of the Board

- Chairman and CEO of Vertex Pharmaceuticals
- PhD, MD, BA (U. Chicago)
- Physician scientist with deep experience across all aspects of the biotech and pharmaceutical industries
- Current Director of PathAI, Quest Diagnostics, and Mass Mutual Life Insurance Company. Past Director of Millennium, Shire, and Abbott

Aditya Khosla, PhD

Co-Founder & CTO

- PhD, Machine Learning and Computer Vision (MIT), MS (Stanford), BS (Caltech)
- Developed new methods in computer vision, including eye-tracking, prediction of image memorability, and visualization of deep networks
- Published over 30 papers in leading venues in the fields of deep learning, computer vision and neuroscience



Stanley Lapidus

Director

- Current Director of PathAI, Atlas Genetics, Fractyl Laboratories, and T2 Biosystems
- Founder and former executive of multiple biotech companies, including Cytac, EXACT Sciences, Helicos BioSciences, and SynapDX
- More than 30 years' experience and major impact in medical diagnostics.
- BA (Cooper Union)

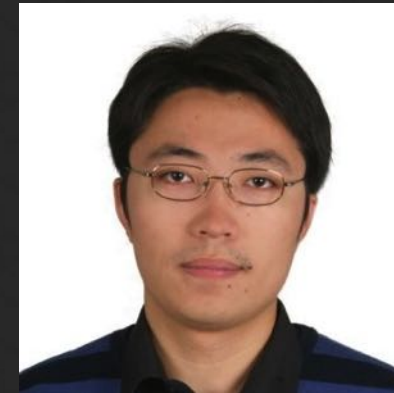


Executive Team



Esther Abels

VP, Clinical & Regulatory Affairs
Previous: Philips Digital Pathology Solutions (led industry-first FDA approval for whole slide imaging)
Education: MSc in Biomedical Science from University of Nijmegen



Dayong Wang

VP, Machine Learning
Previous: Harvard Medical School, won Camelyon Challenge
Education: PhD in Computer Science, Nanyang Technical University



Jackson Wilkinson

VP, Product & Design
Previous: Care.com, LinkedIn
Education: BA from Bowdoin College



Ilan Wapinski

Director, Computational Biology
Previous: EnEvolv, Harvard Medical School
Education: PhD in Computational Biology from Harvard University



Tiffany Freitas

Chief Business Officer
Previous: Vestmark, Disney, Bain & Company
Education: MBA from Harvard Business School



Hunter Elliott

Director, Machine Learning Research
Previous: Harvard Medical School
Education: PhD in Biophysics from The Scripps Research Institute

Platform Overview

Fully Integrated Cloud-based AI Platform for Digital Pathology

WITH APPLICATIONS FOR

Translational Research

Analysis of biomarker prevalence studies
and clinical trials

Drug Advancement and CDx

Early phase trial design, companion and
complementary diagnostic algorithms



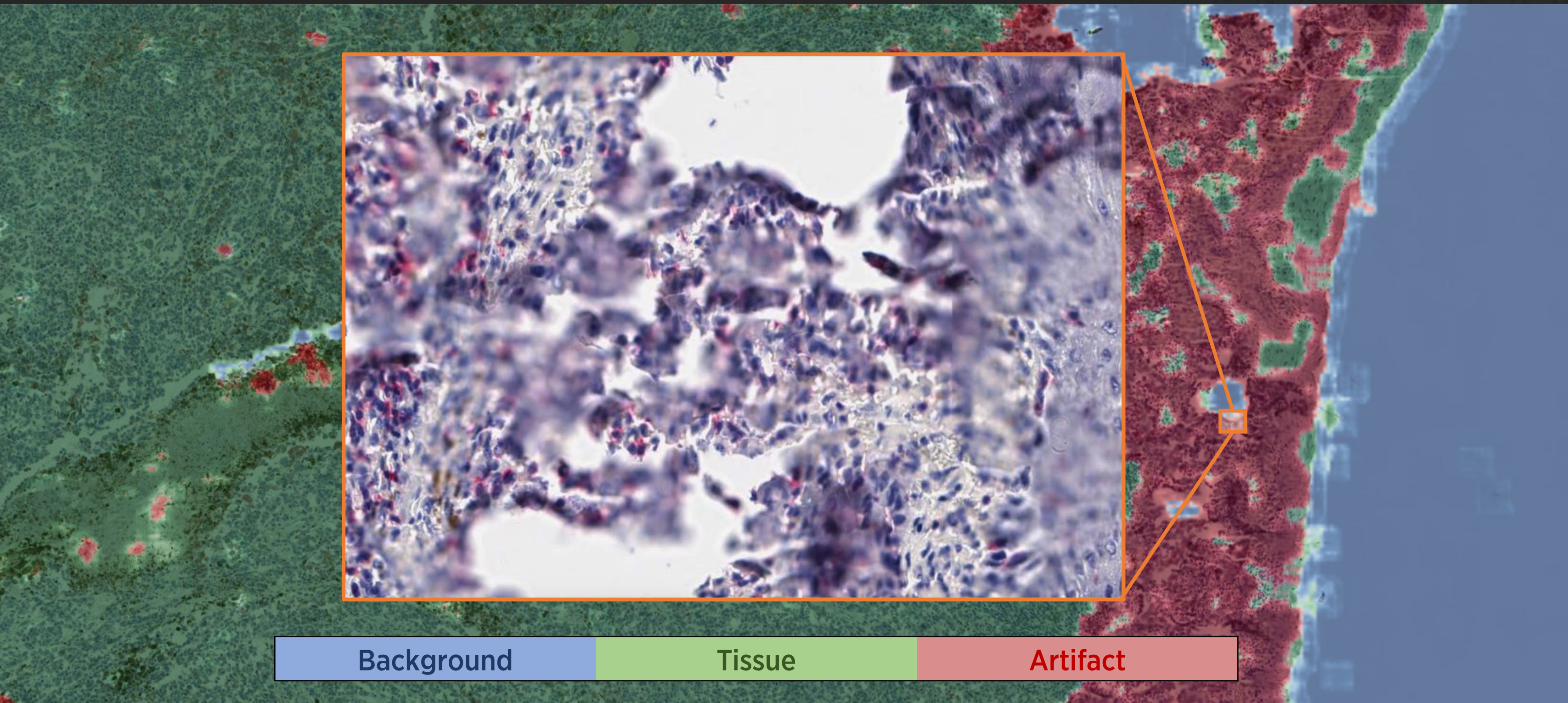
Data Storage and Curation

Pathologist Network

Deep Learning Algorithms

Results and Reporting

Automatic Evaluation of Slide Quality



Extensive Slide Search & Data Standardization

Slides Search

 Filter Images
Choose criteria

TCGA

TCGA

Any case

Any stain

Any group

Original file name

Overlays:

☐ Yes ☐ No ☒ Either

Annotations:

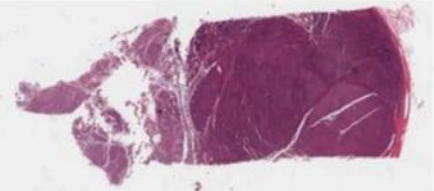
☐ Yes ☐ No ☒ Either

30872 matching images

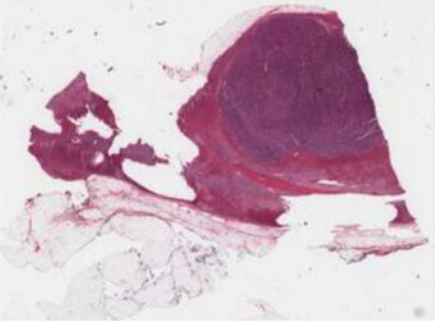
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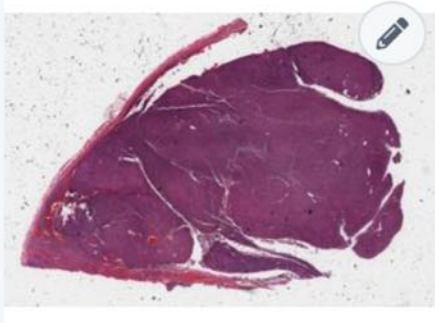
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Frozen



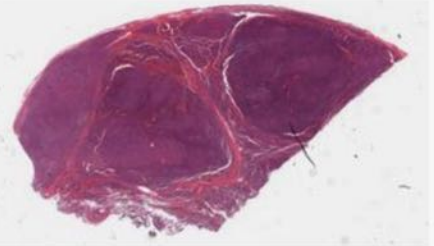
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H & E



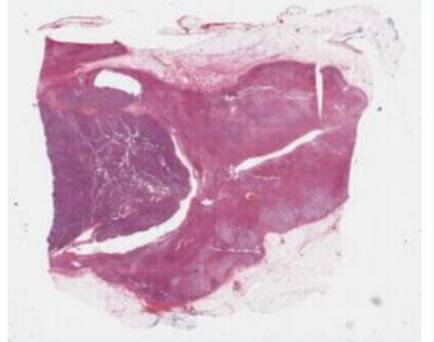
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H & E



Case TCGA-OR-A5J1
H & E



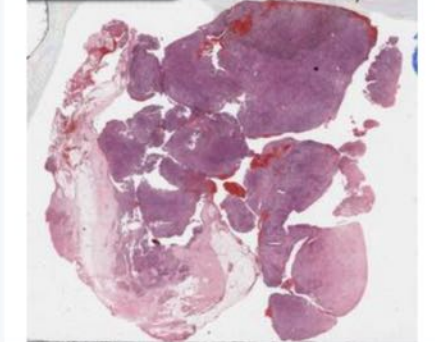
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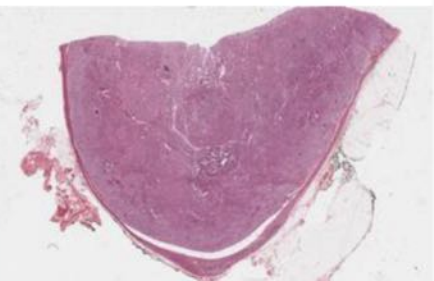
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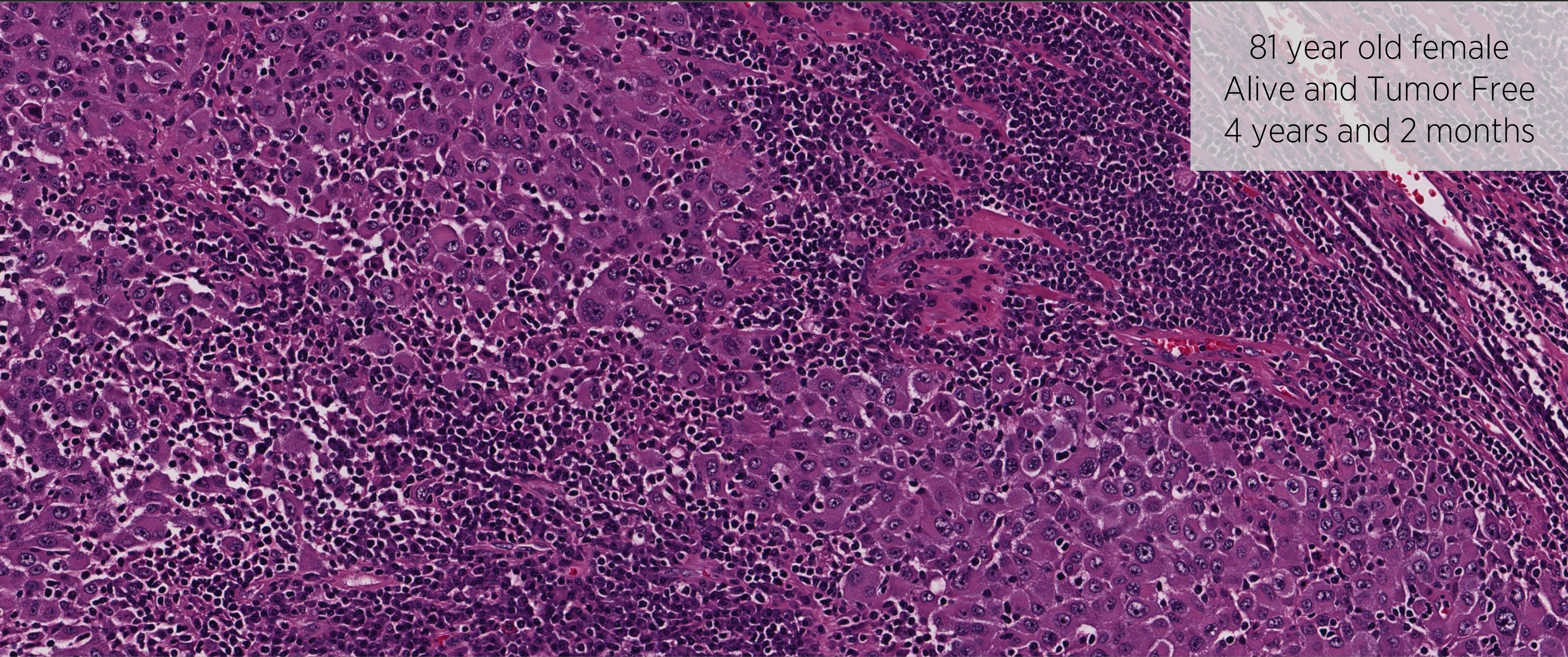
Case TCGA-OR-A5J2
Frozen



Case TCGA-OR-A5J2
H & E



Automatic Interpretation of Cells & Tissue Types



81 year old female
Alive and Tumor Free
4 years and 2 months

Automatic Interpretation of Cells & Tissue Types

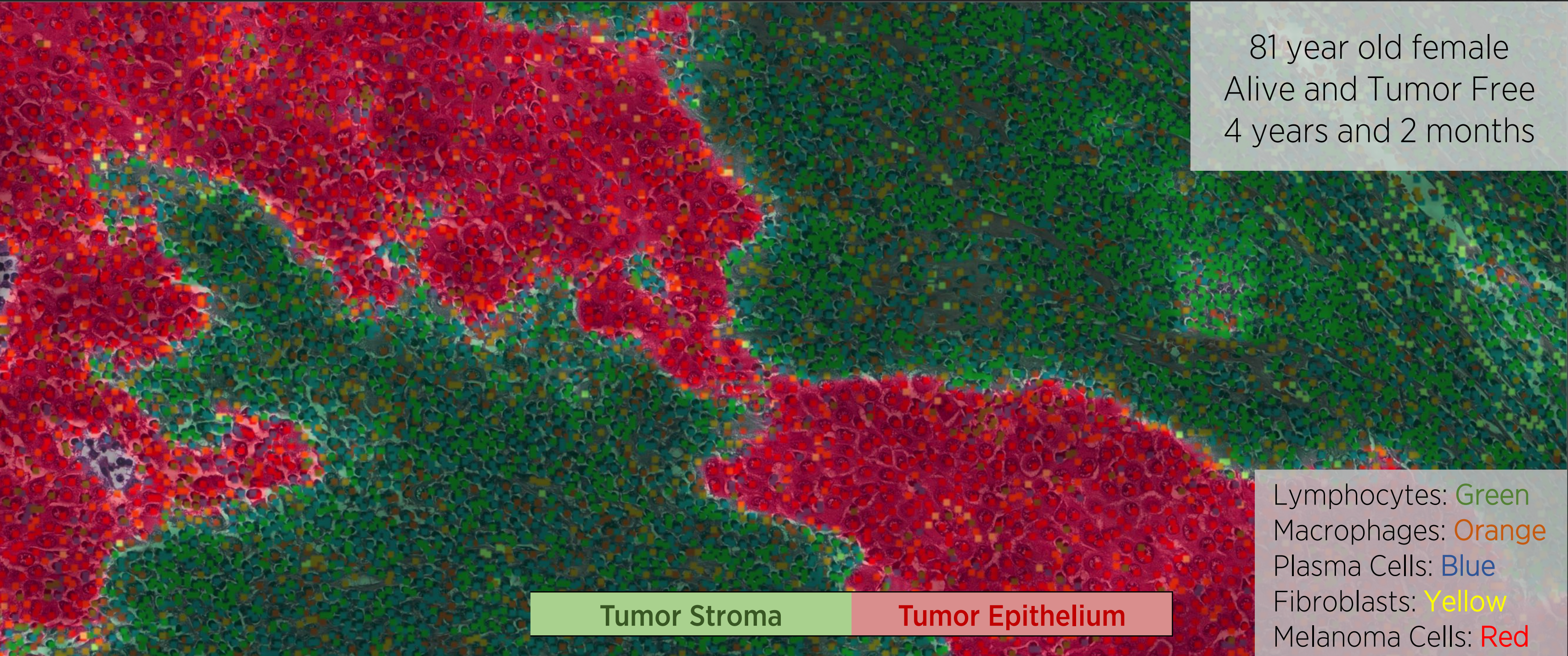
81 year old female
Alive and Tumor Free
4 years and 2 months

Tumor Stroma

Tumor Epithelium

Automatic Interpretation of Cells & Tissue Types

81 year old female
Alive and Tumor Free
4 years and 2 months



Tumor Stroma

Tumor Epithelium

Lymphocytes: Green
Macrophages: Orange
Plasma Cells: Blue
Fibroblasts: Yellow
Melanoma Cells: Red

Interactive Reports & Live Project Progress

PharmaCorp

Projects Slides ? JA

Projects

IN PROGRESS (2)

Melanoma Study

The goal of this project is to leverage the PathAI platform to quantitate cellular and morphologic phenotypes from IHC (PD-L1) stained images in melanoma clinical trial data sets. The algorithms developed will be validated using exhaustive annotations on selected window frames, and algorithm improvements will be implemented to include new features and rule-based region-of-interest (ROI) selection. Once validated, extracted image features will be used to find associations with patient clinical outcomes (Best OR, PFS, OS).

Predictive analysis

COMPLETED (2)

Bladder Research

The goal of this project is to leverage the PathAI platform to quantitate cellular and morphologic phenotypes from IHC (PD-L1) stained images in melanoma clinical trial data sets. The algorithms developed will be validated using exhaustive annotations on selected window frames, and algorithm improvements will be implemented to include new features and rule-based region-of-interest (ROI) selection. Once validated, extracted image features will be used to find associations with patient clinical outcomes (Best OR, PFS, OS).

Completed May 15, 2018

PROJECT

Melanoma Study Project

OVERVIEW

REPORT

CASES


Melanoma Study Project

Overview

The goal of this project is to leverage the PathAI platform to quantitate cellular and morphologic phenotypes from IHC (PD-L1) stained images in melanoma clinical trial data sets. The algorithms developed will be validated using exhaustive annotations on selected window frames, and algorithm improvements will be implemented to include new features and rule-based region-of-interest (ROI) selection. Once validated, extracted image features will be used to find associations with patient clinical outcomes (Best OR, PFS, OS).

KEY RESULTS

Our multivariate model separates patients into XX responders and non-responders



Progress

Predictive analysis

PathAI added a key result. 2d ago

Project status changed to Predictive analysis. 3d ago

PathAI uploaded a report. 3d ago

PathAI released slide overlays Cell Detection v1, Tissue map V1 21d ago

Project status changed to Extracting features

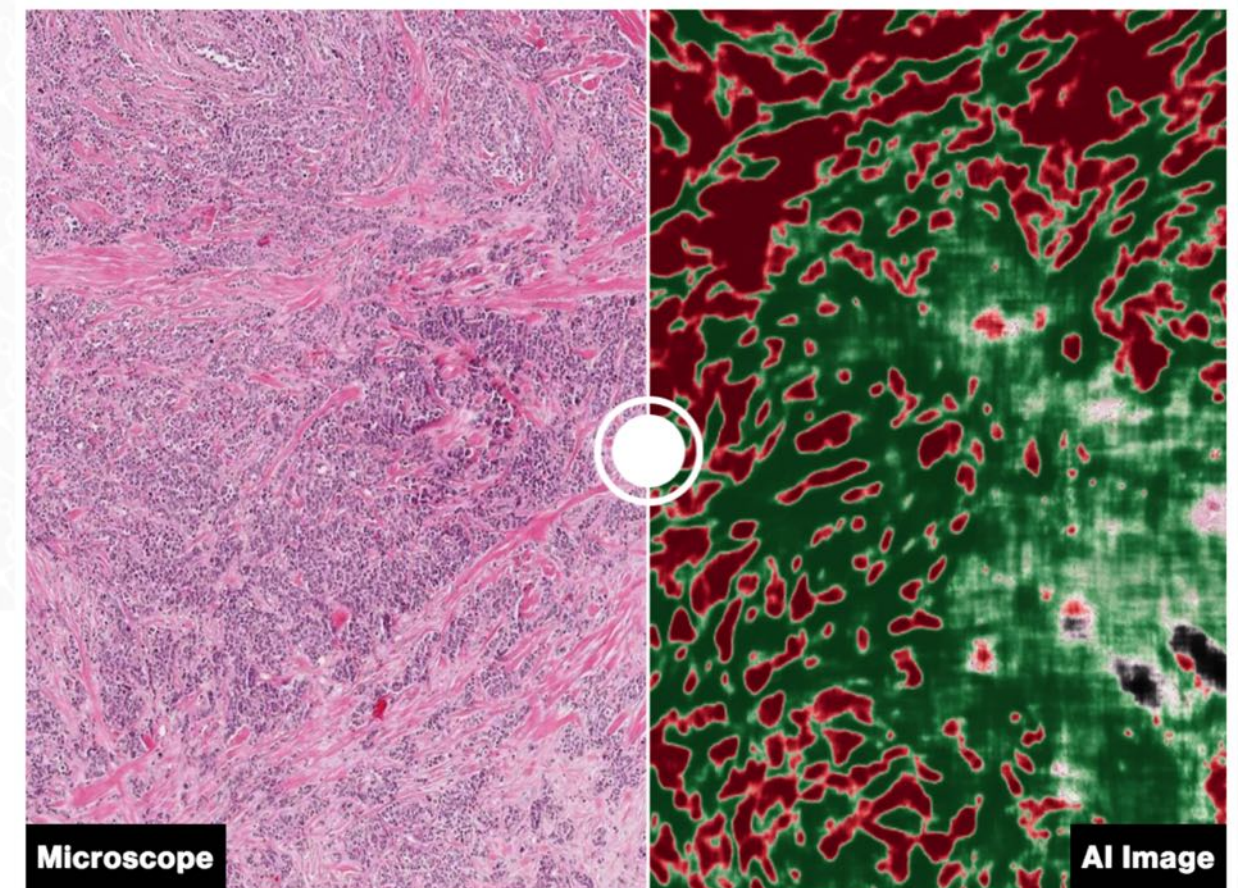
Case Study: PathAI Research Collaboration with Novartis

Artificial intelligence decodes cancer pathology images

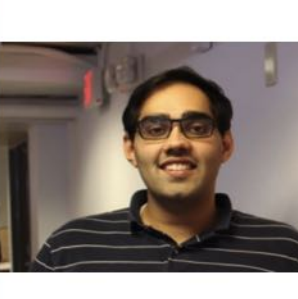
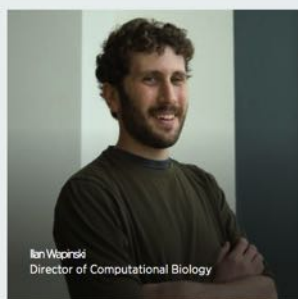
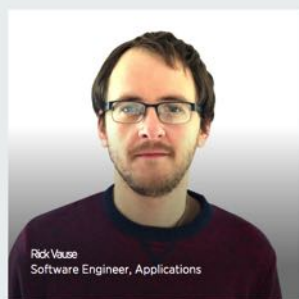
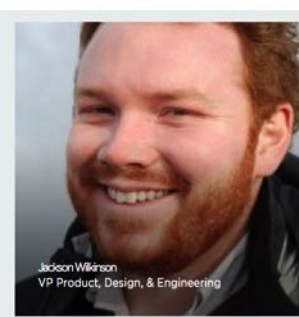
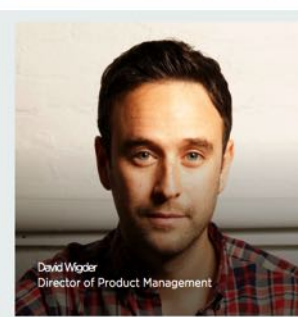
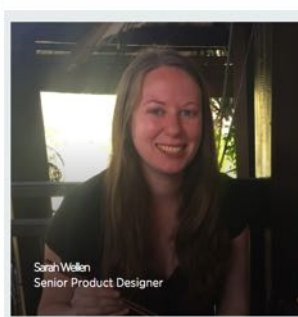
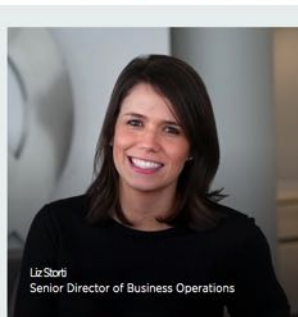
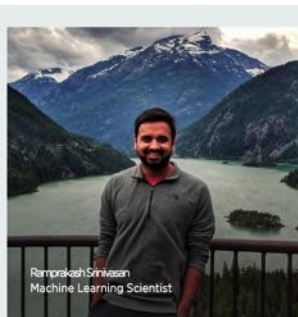
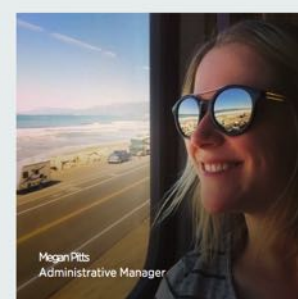
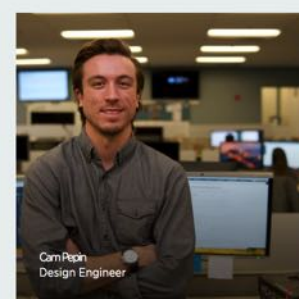
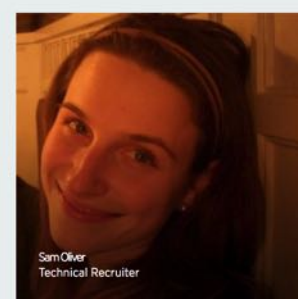
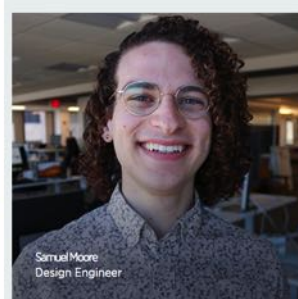
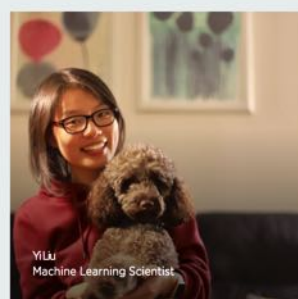
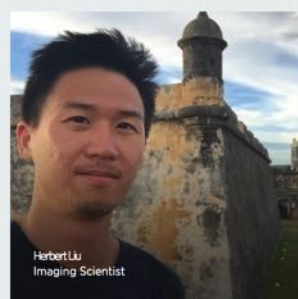
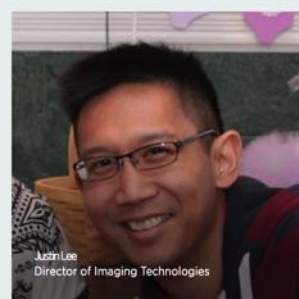
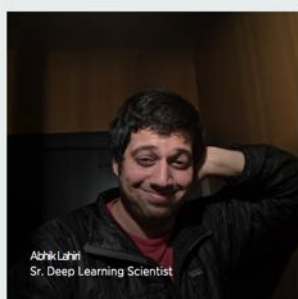
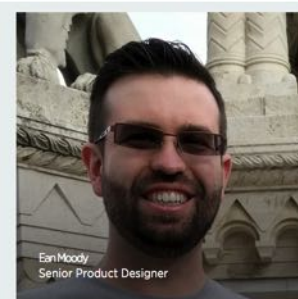
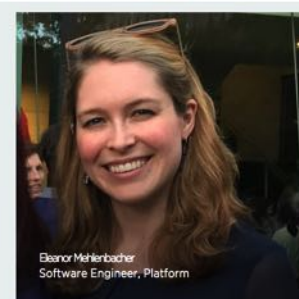
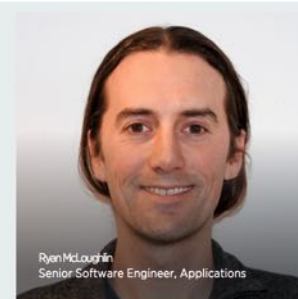
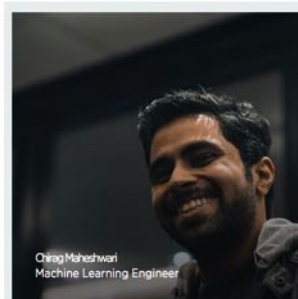
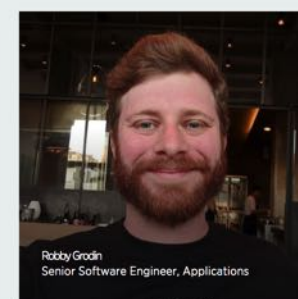
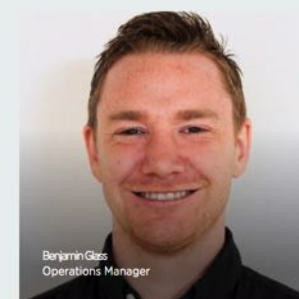
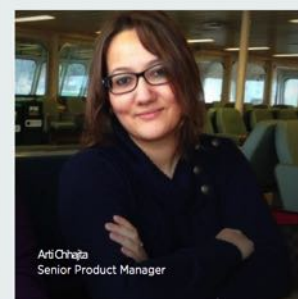
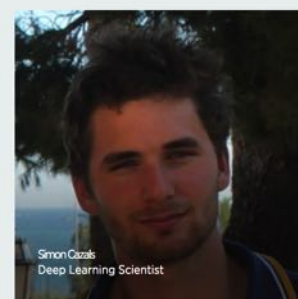
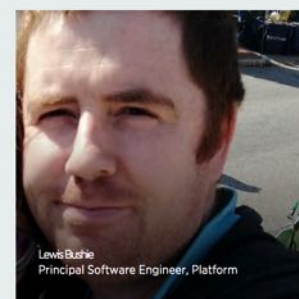
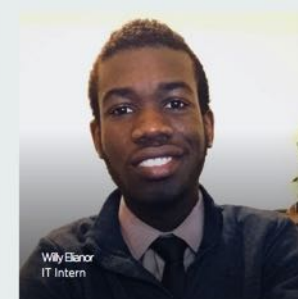
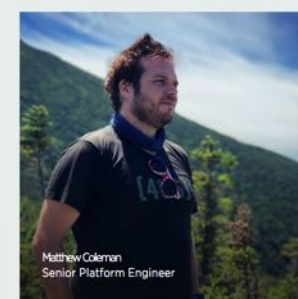
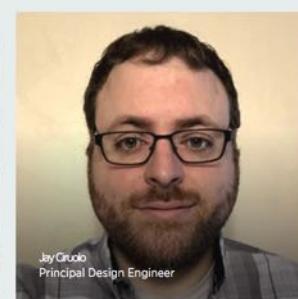
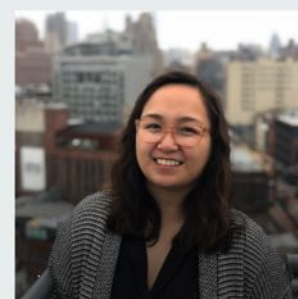
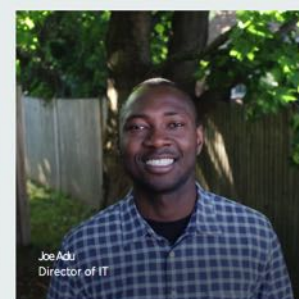
Novartis researchers are collaborating with tech startup PathAI to search for hidden information in pathology slides.

Elizabeth Dougherty | November 12, 2018

“We want to create a platform that enables the field of pathology to support the accelerating pace of drug development.”



Thanks to the PathAI Team





PathAI is the world's leading computational pathology company.

Organized, accessible,
large-scale data to fuel global AI
initiatives and discovery efforts.

Extract new value from clinical
trial & pathology data, accelerate
drug development & approval,
and mitigate late-stage failures.