



浙江大学爱丁堡大学联合学院

ZJU-UoE Institute

## Lecture 20 - Recent advances in image analysis using deep learning

### Part 2 - Image segmentation

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## Learning objectives

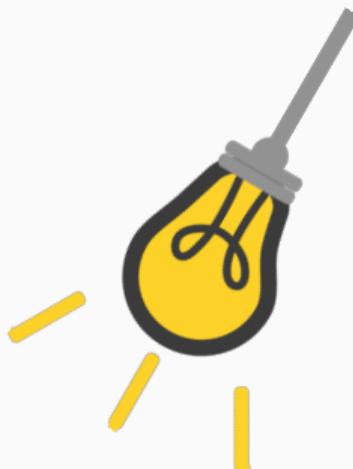
- Discuss recent advances in image analysis using deep learning.

## Learning objectives

- Discuss recent advances in image analysis using deep learning.

Today we are going to analyse recent articles related to image segmentation using deep learning.

- The StarDist and StarDist3D methods for cell segmentation.
  - Schmidt et al. 2018 - Cell Detection with Star-convex Polygons
  - Weigert et al. 2020 - Star-convex Polyhedra for 3D Object Detection and Segmentation in Microscopy
- TissueNet and Mesmer
  - Greenwald et al. 2021 - Whole-cell segmentation of tissue images with human-level performance using large-scale data annotation and deep learning



## **StarDist and StarDist3D**

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## Instance segmentation of cell nuclei

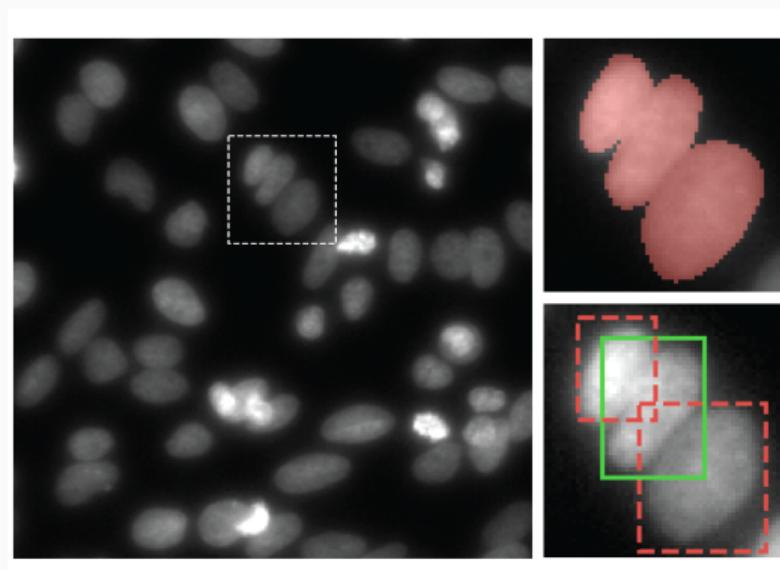
Instance segmentation of microscopy images is a difficult task.

*Top-down approaches* perform semantic segmentation, then split instances.

**Problem:** nearby cells in crowded images fused together.

*Bottom-up approaches* roughly define cells (bounding boxes), then classify pixels within each box.

**Problem:** NMS steps might miss nearby nuclei.



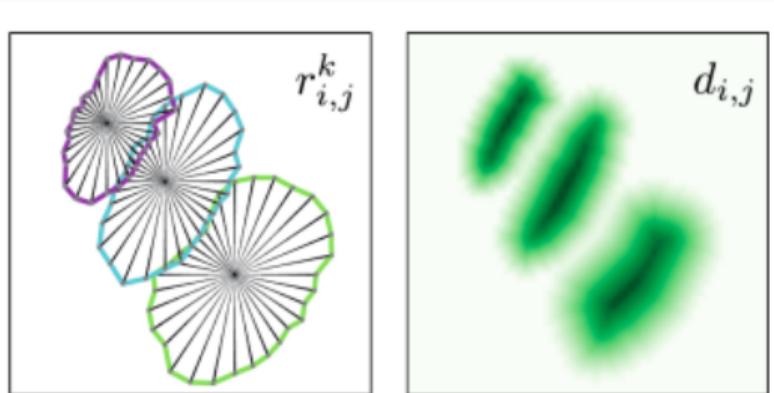
## Cell Detection with Star-convex Polygons

Uwe Schmidt<sup>1,\*</sup>, Martin Weigert<sup>1,\*</sup>, Coleman Broaddus<sup>1</sup>, and Gene Myers<sup>1,2</sup>

*“To alleviate the aforementioned problems, we propose StarDist, a cell detection method that predicts a shape representation which is flexible enough such that – without refinement – the accuracy of the localization can compete with that of instance segmentation methods. To that end, we use **star-convex polygons** that we find well-suited to approximate the typically roundish shapes of cell nuclei in microscopy images.”*

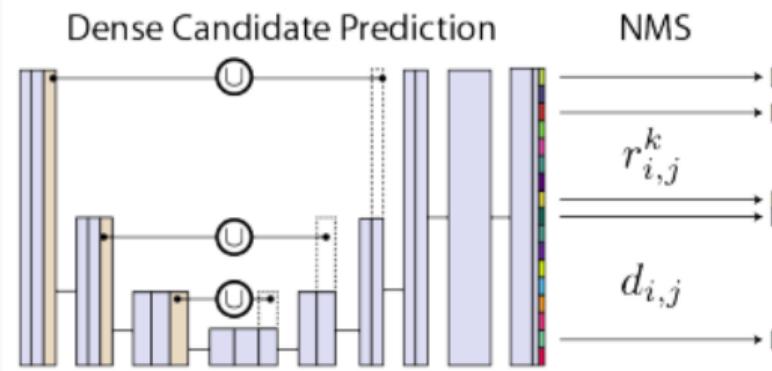
# StarDist: method

Radial  
distances to  
border



Object  
probabilities

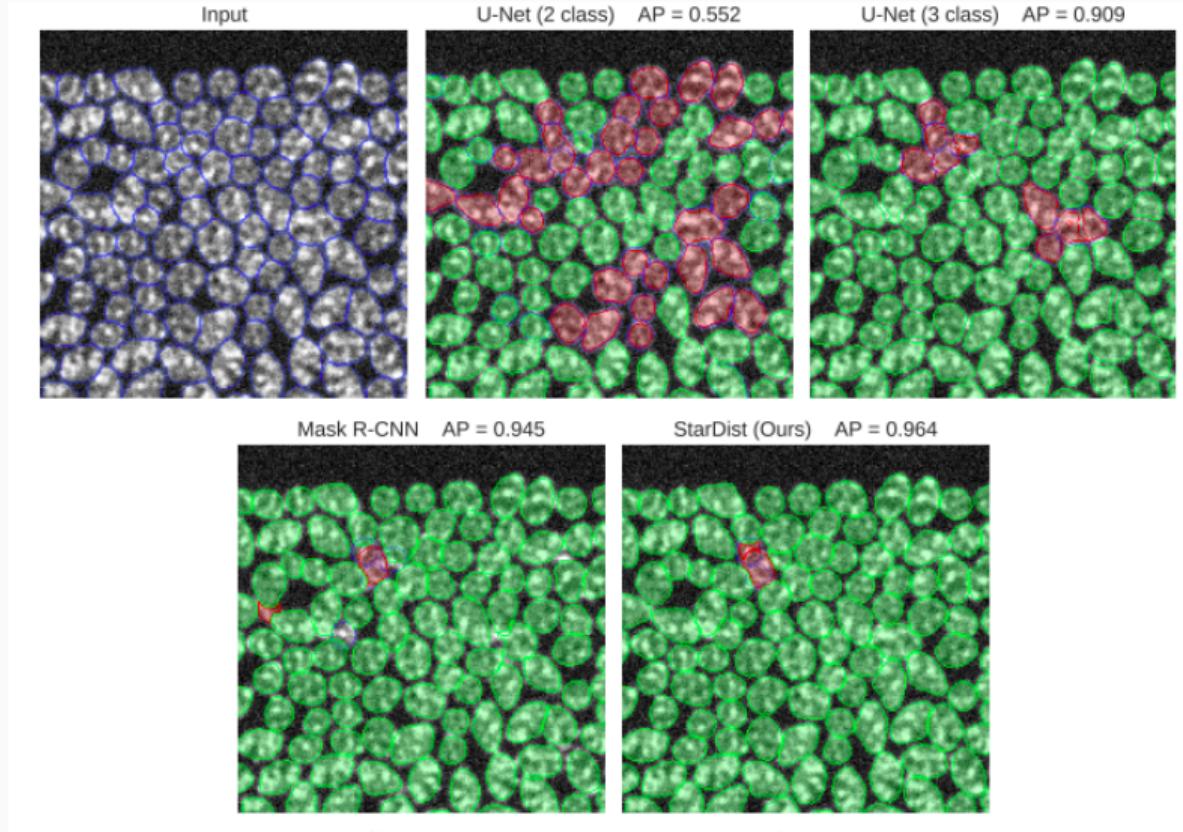
U-Net  
architecture



Distances → MAE loss

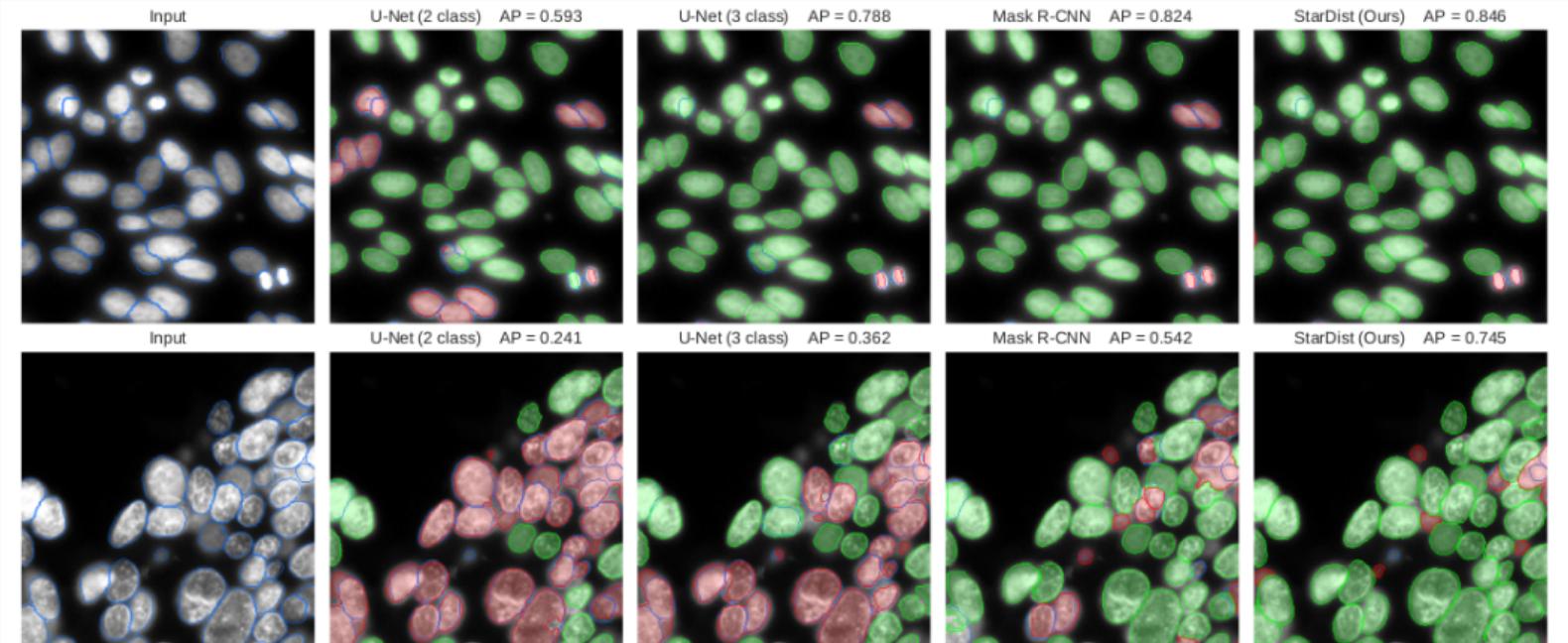
Obj. prob. → binary  
cross-entropy loss

## Results



StarDist outperforms many common instance segmentation methods.

# Results



StarDist outperforms many common instance segmentation methods.

# Can we extend StarDist to 3D?

## Star-convex Polyhedra for 3D Object Detection and Segmentation in Microscopy

Martin Weigert<sup>1,2,3,\*</sup>    Uwe Schmidt<sup>2,3,\*</sup>    Robert Haase<sup>2,3</sup>    Ko Sugawara<sup>4,5</sup>    Gene Myers<sup>2,3</sup>

<sup>1</sup>Institute of Bioengineering, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

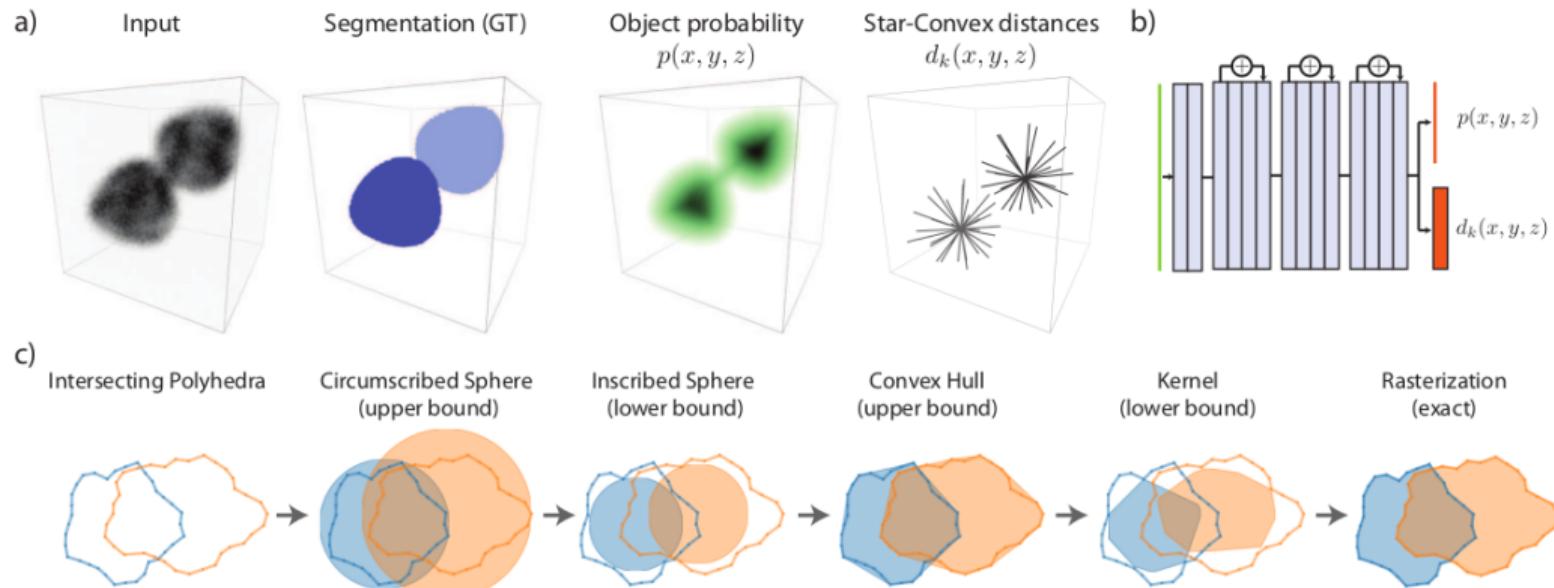
<sup>2</sup>Max Planck Institute of Molecular Cell Biology and Genetics (MPI-CBG), Dresden, Germany

<sup>3</sup>Center for Systems Biology Dresden (CSBD), Germany

<sup>4</sup>Institut de Génomique Fonctionnelle de Lyon (IGFL), École Normale Supérieure de Lyon, France

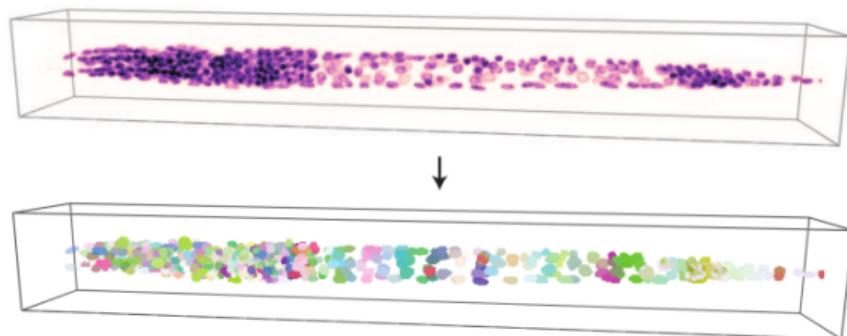
<sup>5</sup>Centre National de la Recherche Scientifique (CNRS), Paris, France

# StarDist3D - method

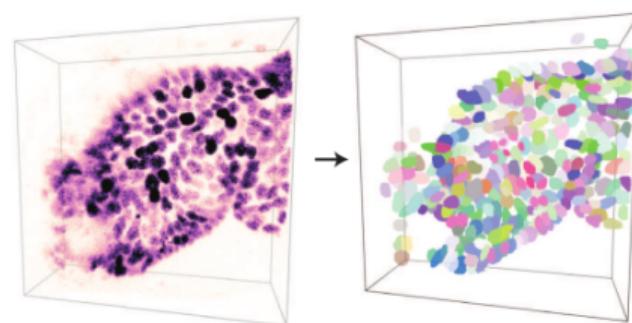


## Results

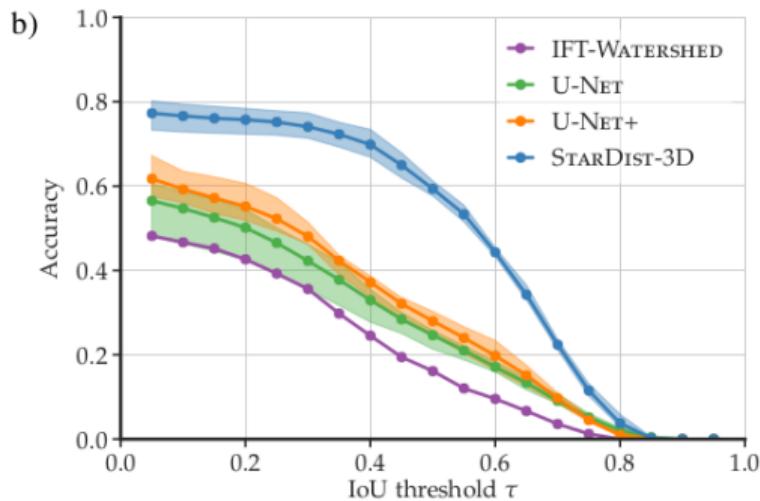
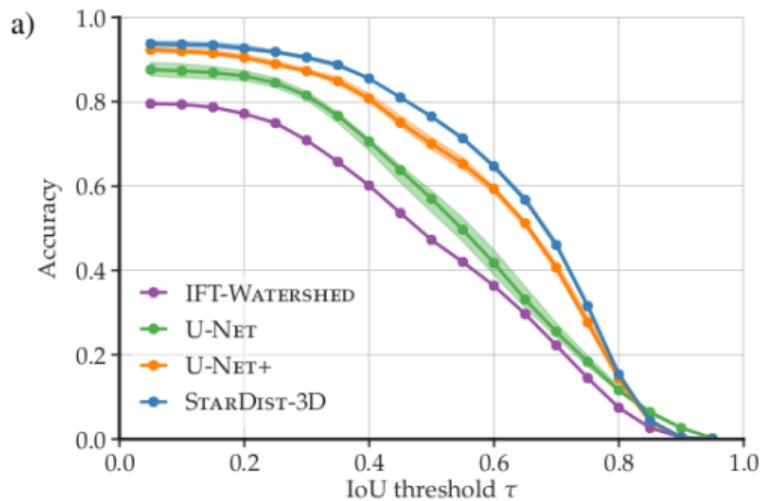
WORM



PARHYALE



## Comparison with existing methods



**TissueNet**

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## The problem

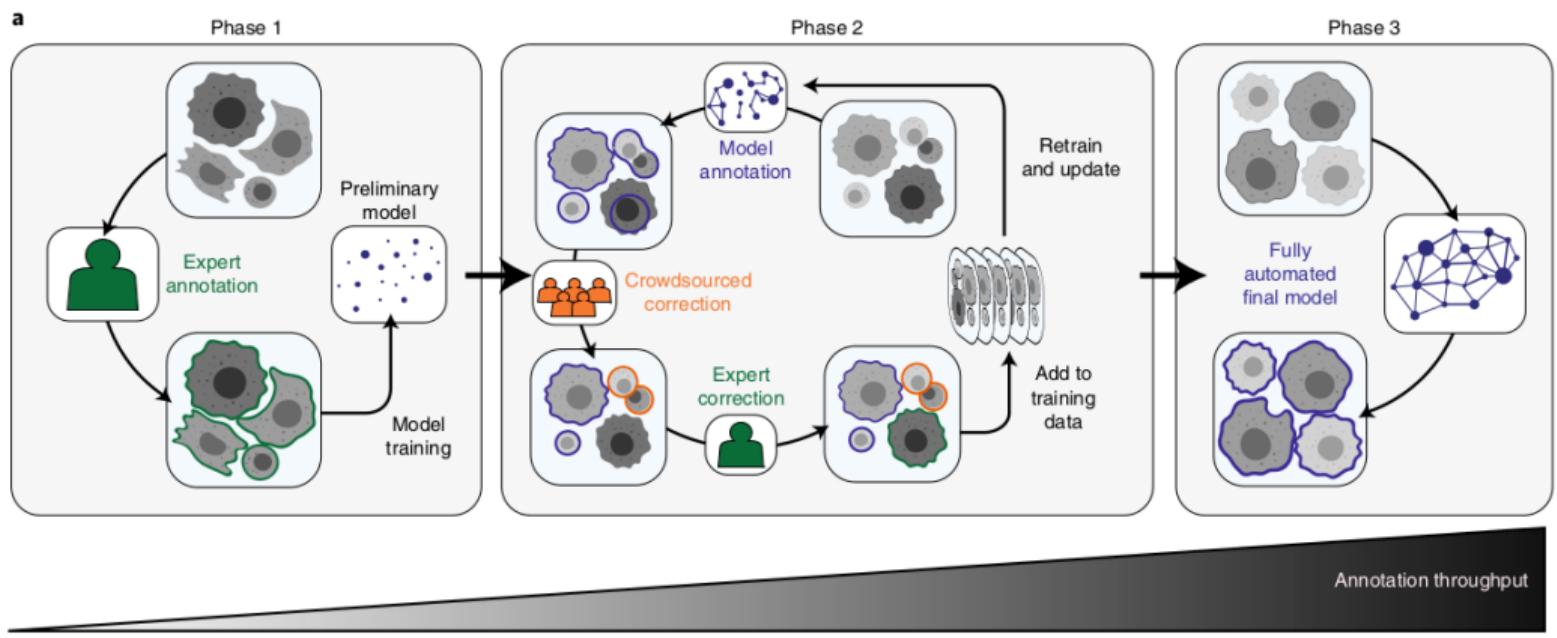
- Lack of a generalized algorithm for locating single cells in images
- Deep learning requires a lot of ground-truth data (difficult to get!) for high accuracy segmentation
- Public datasets only annotate nuclei, not the entire cell

# Whole-cell segmentation of tissue images with human-level performance using large-scale data annotation and deep learning

Noah F. Greenwald <sup>1,2,11</sup>, Geneva Miller  <sup>3,11</sup>, Erick Moen <sup>3</sup>, Alex Kong <sup>2</sup>, Adam Kagel <sup>2</sup>, Thomas Dougherty <sup>3</sup>, Christine Camacho Fullaway <sup>2</sup>, Brianna J. McIntosh  <sup>1</sup>, Ke Xuan Leow  <sup>1,2</sup>, Morgan Sarah Schwartz <sup>3</sup>, Cole Pavelchek  <sup>3,9</sup>, Sunny Cui  <sup>4,10</sup>, Isabella Camplisson <sup>3</sup>, Omer Bar-Tal  <sup>5</sup>, Jaiveer Singh <sup>2</sup>, Mara Fong <sup>2,6</sup>, Gautam Chaudhry  <sup>2</sup>, Zion Abraham <sup>2</sup>, Jackson Moseley <sup>2</sup>, Shiri Warshawsky <sup>2</sup>, Erin Soon <sup>2,7</sup>, Shirley Greenbaum  <sup>2</sup>, Tyler Risom <sup>2</sup>, Travis Hollmann  <sup>8</sup>, Sean C. Bendall  <sup>2</sup>, Leeat Keren  <sup>5</sup>, William Graf  <sup>3</sup>, Michael Angelo  <sup>2</sup>  and David Van Valen  <sup>3</sup> 

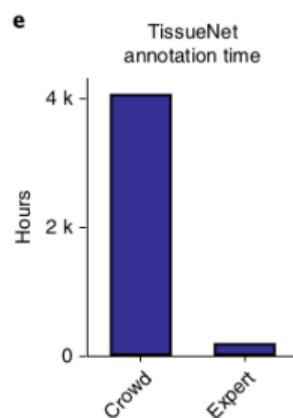
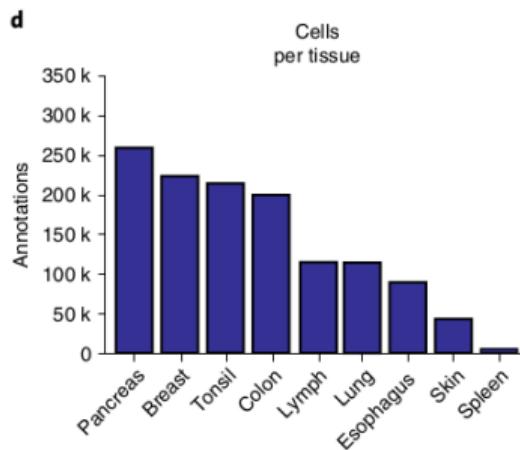
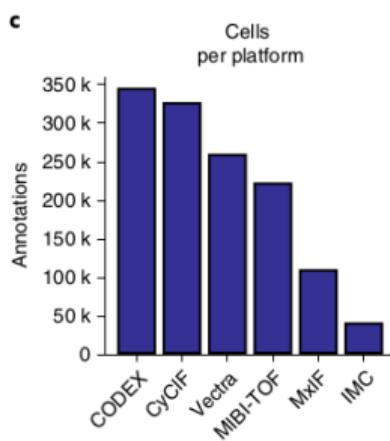
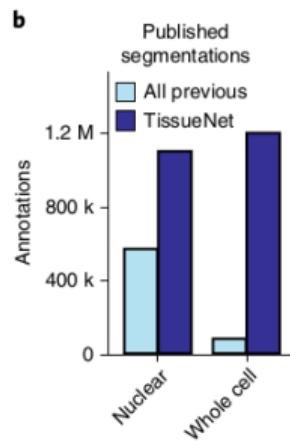
- **TissueNet:** “a comprehensive segmentation dataset of >1 million paired whole-cell and nuclear annotations.”
- **Mesmer:** a deep-learning segmentation algorithm.
- **DeepCell:** an open-source collection of software libraries, to create a web interface for using Mesmer, as well as plugins for ImageJ and QuPath.

# TissueNet development

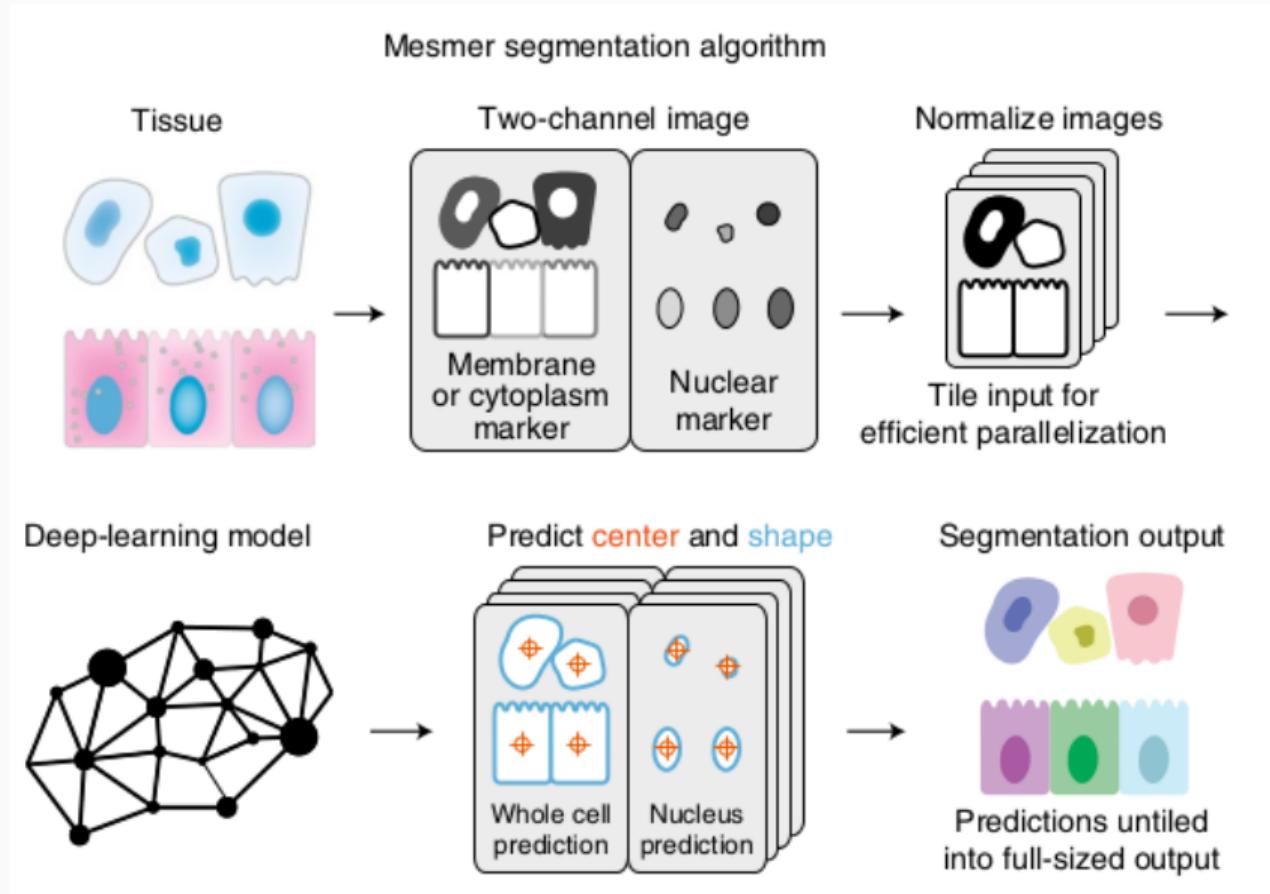


TissueNet was developed through a crowdsourcing approach

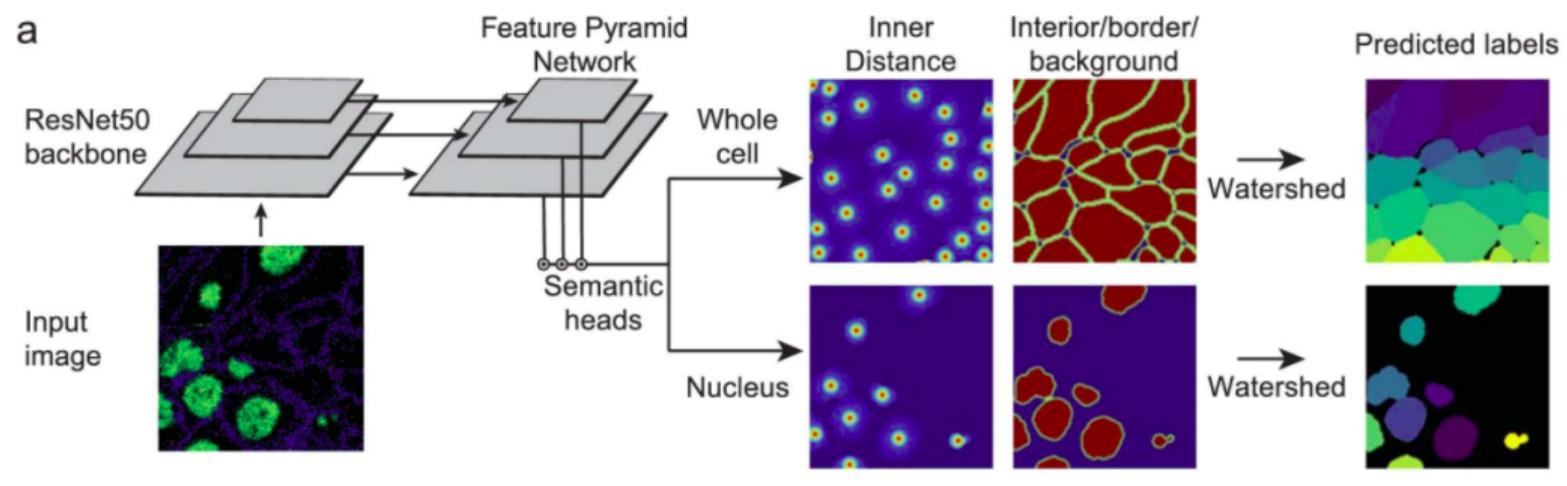
# TissueNet - some statistics



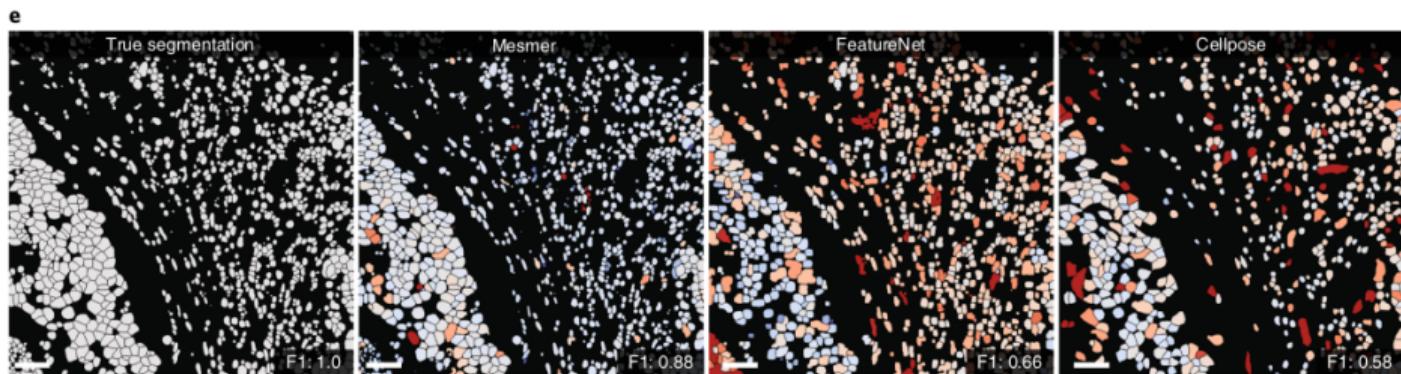
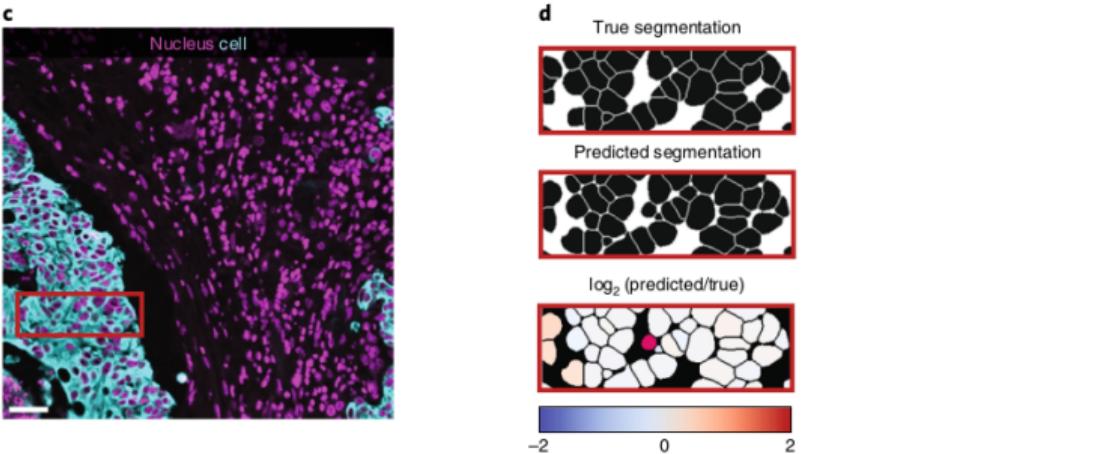
# The Mesmer segmentation algorithm



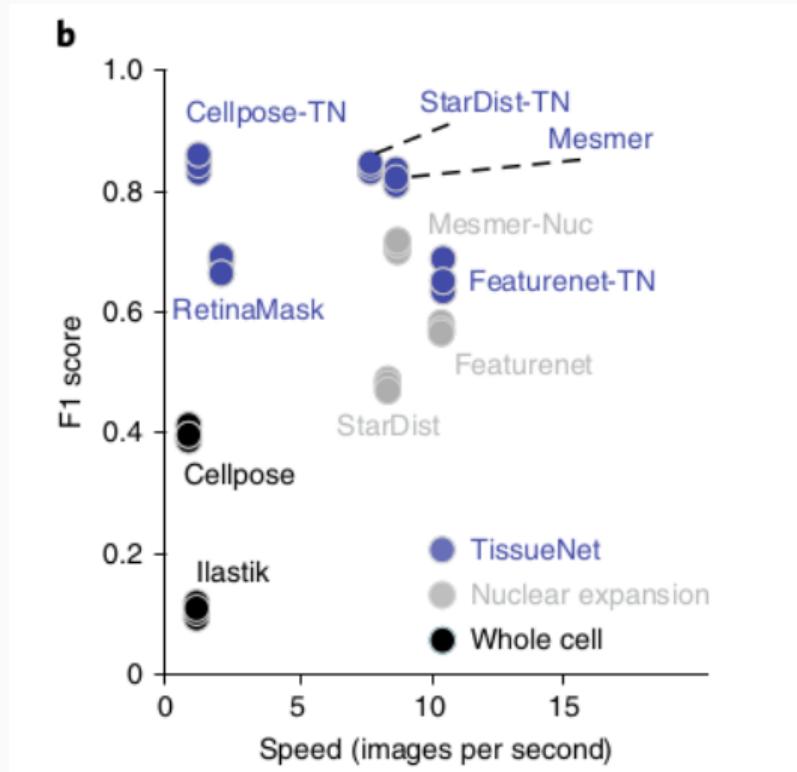
# Mesmer architecture



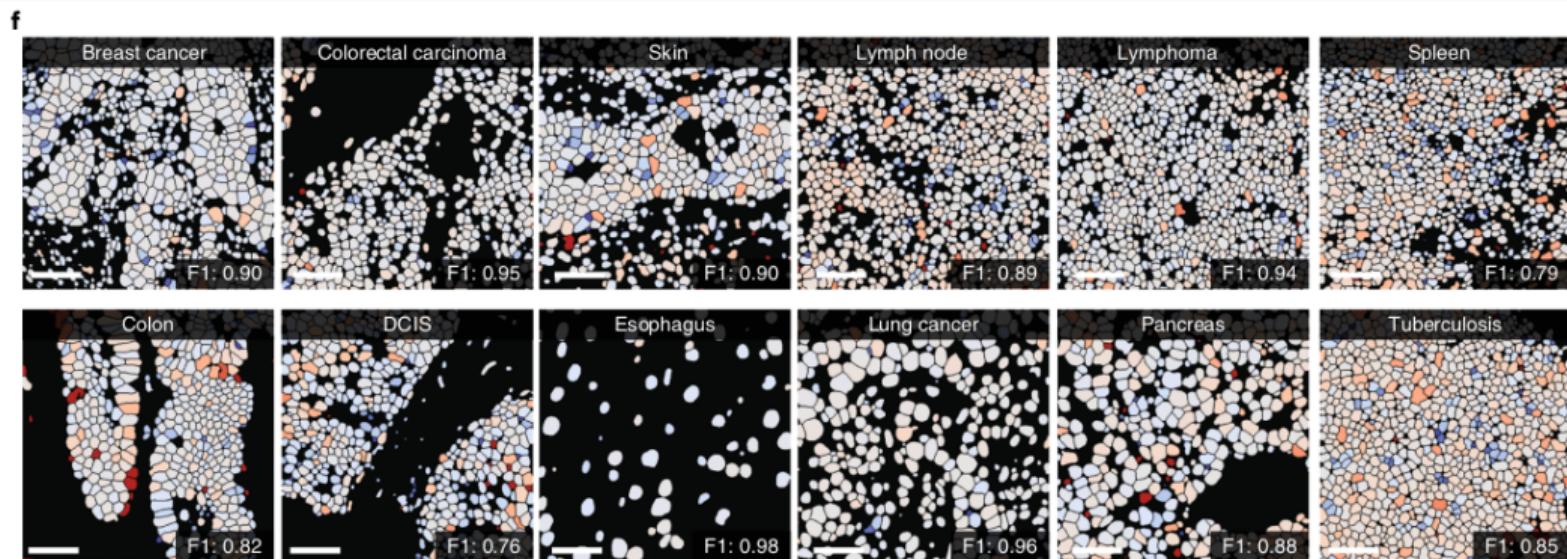
# Segmentation results



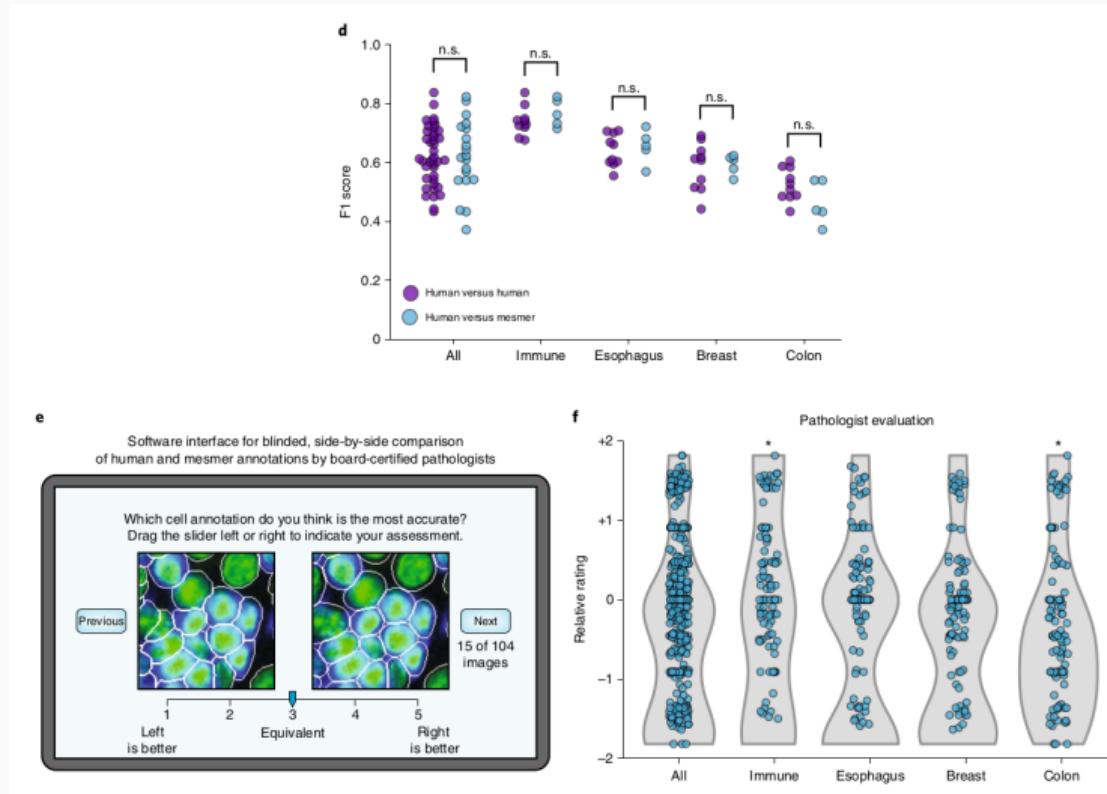
## Segmentation results



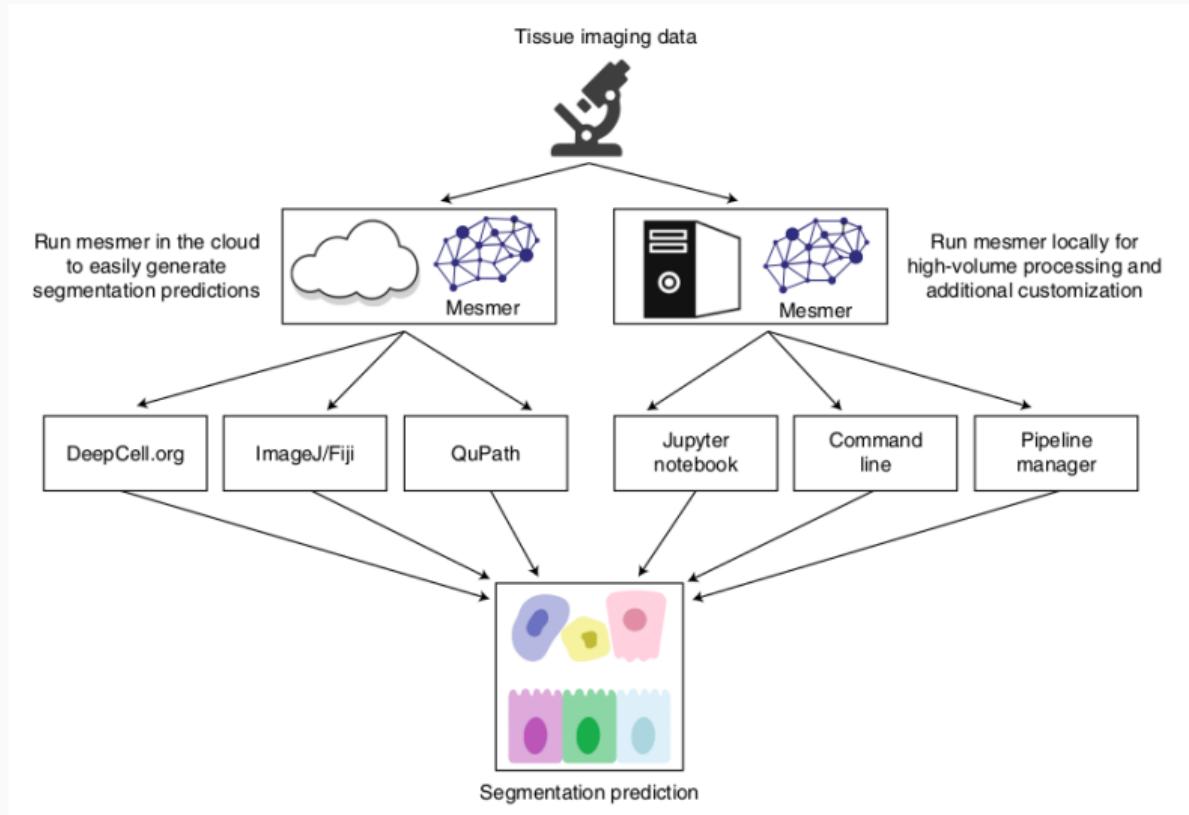
# Segmentation of different tissues



# Human-level performance in segmentation



# Mesmer deployment



The end!

That's the end of the course  
Hope you enjoyed it!

(and looking forward to see your assignments!)