

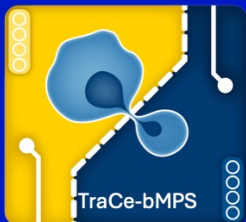


University  
of Rochester

# Build Your Own MPS: The Modular $\mu$ SiM Platform for Modeling Barrier Systems

James L. McGrath, PhD ; Alexis Feidler, MS; Ahmet Gurcan, MS and friends

University of Rochester · Translational Center for Barrier Microphysiological Systems



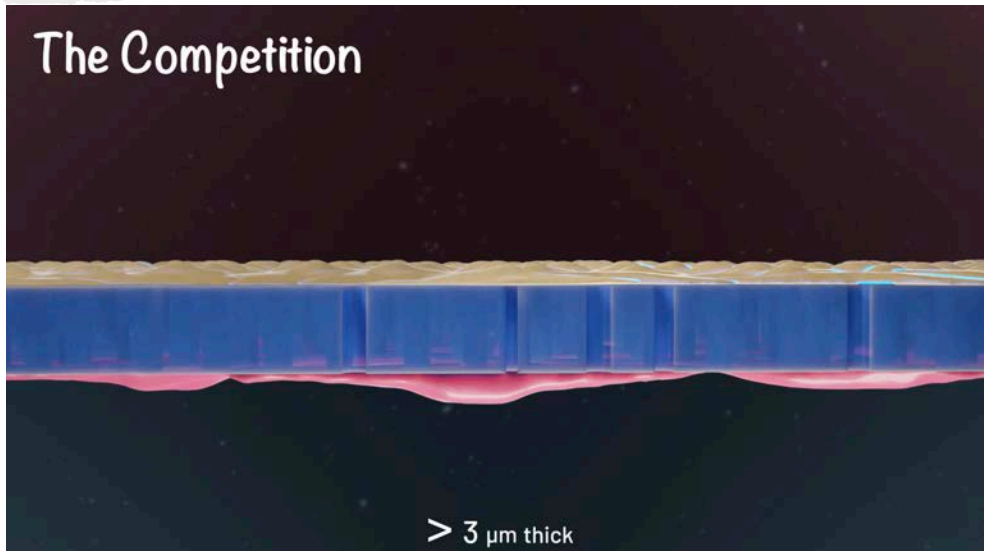
Summer Immersion on Innovative Approaches in Science  
Workshop 1 · Johns Hopkins, Baltimore · June 16, 2026

Co-Founder:

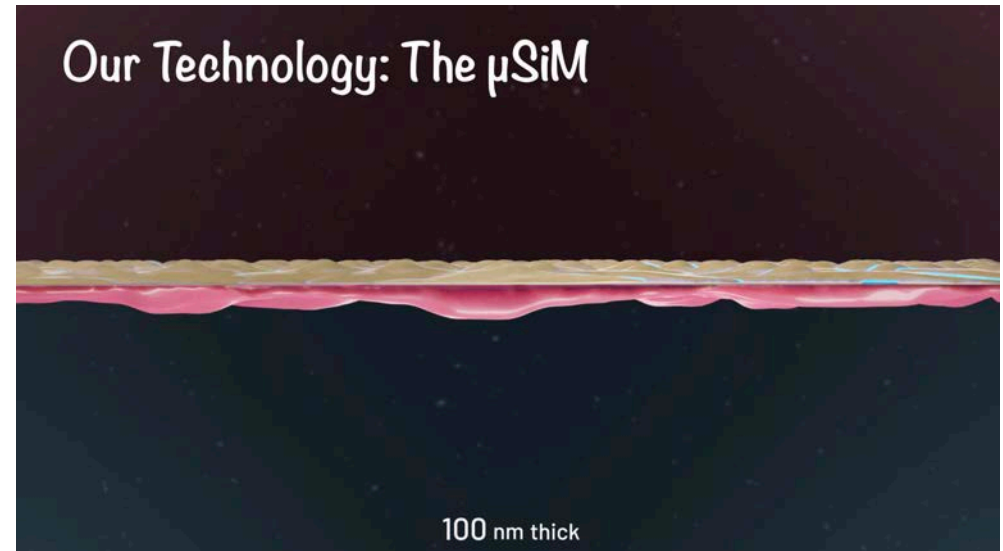


# The $\mu$ SiM Advantage

Now you see it, Now you don't



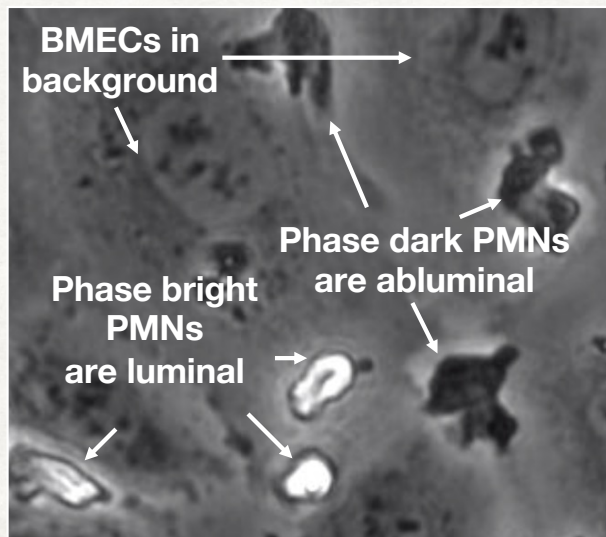
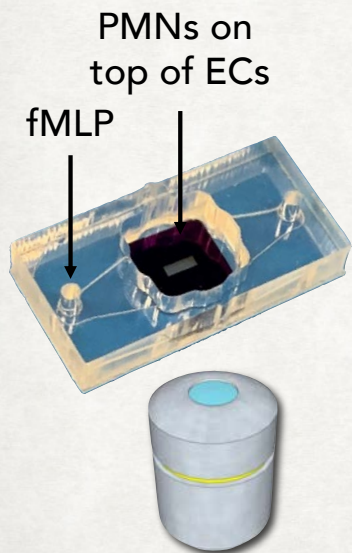
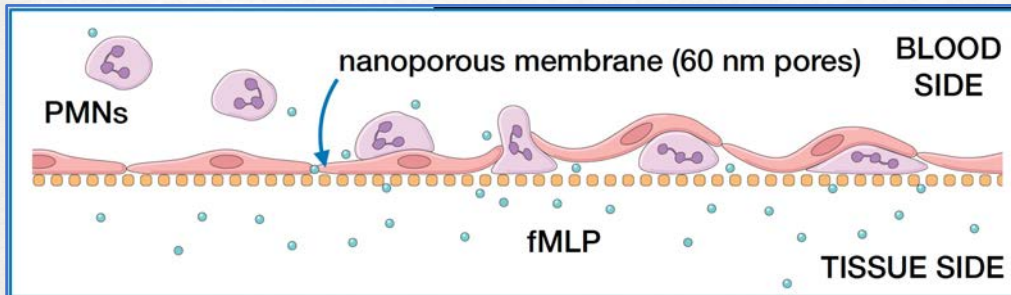
No cell-cell contact and poor imaging



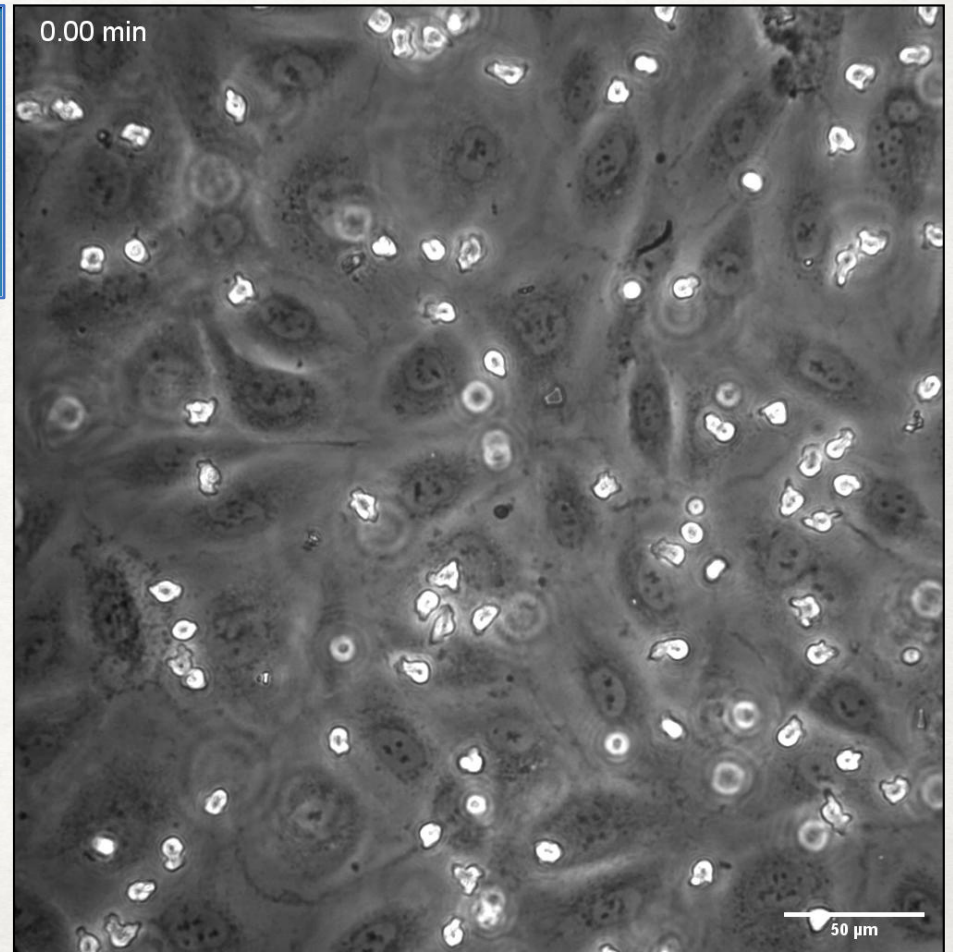
Cell-Cell contact and molecular exchange through millions of nano/micro pores with outstanding imaging

[▶ Play video](#)

# LIVE AND LABEL FREE IMAGING OF LEUKOCYTE TRANSMIGRATION ACROSS AN ENDOTHELIAL BARRIER



Salminen et al., (2020)  
Int. Bio., 12(11), 275–289

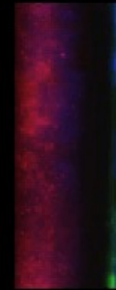
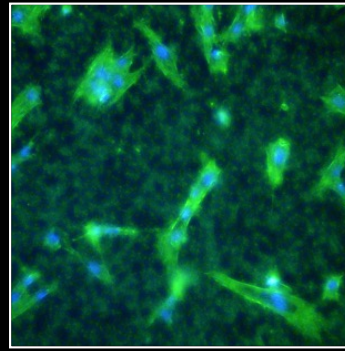
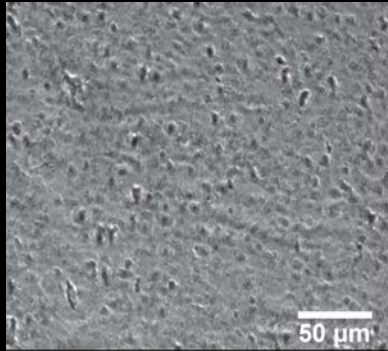
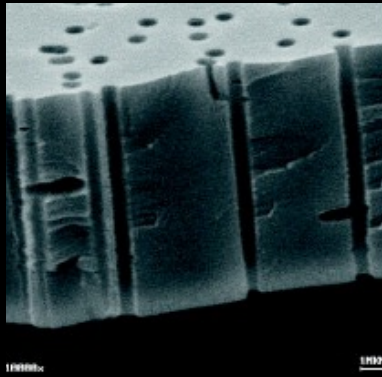


Phase contrast imaging @ 40X

▶ Play video

# GLASS-LIKE IMAGING

Track Etched



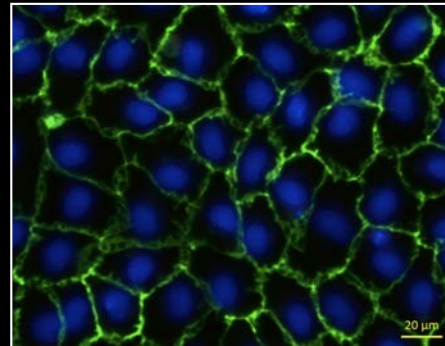
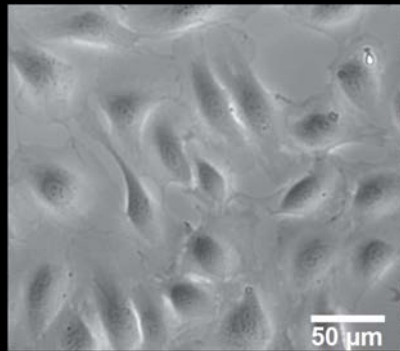
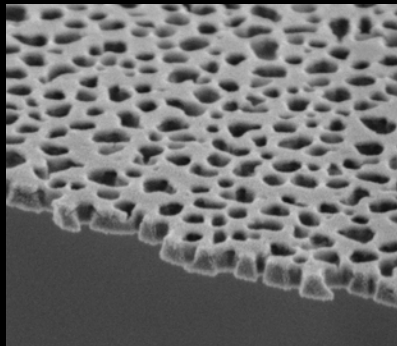
Thick and visible



Thin and invisible



Nanomembranes



SEM

PHASE  
CONTRAST

FLUORESCENCE

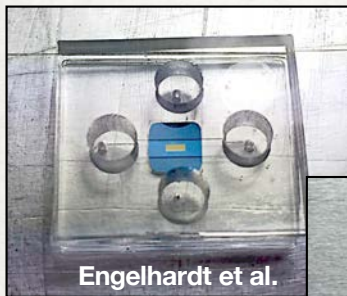
Confocal

 Play video

# Modular $\mu$ SiM: Design *Driven* by Collaboration

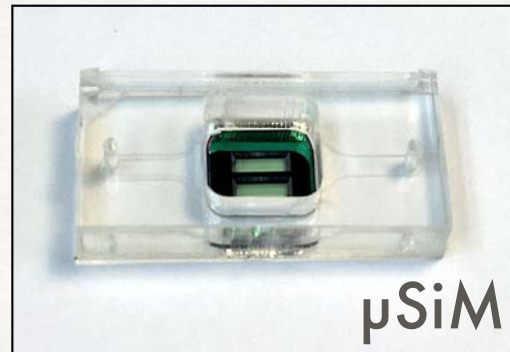
2016-2019

- ▶ Hand built devices: ~ 3-10 devices a week
- ▶ Device-to-device variability
- ▶ Builder-to-builder variability
- ▶ Different needs for every project



Need for 300-500!

2019



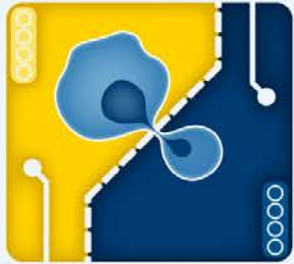
- ▶ Shipped chips, received devices
- ▶ 2 weeks, 300 devices, >95% yield
- ▶ All devices effectively the same
- ▶ Used in genetic screens to discover essential *S. aureus* genes for bone infection in osteomyelitis
- ▶ Scalable production... but only for one project.

So ... 2022



- ▶ The modular  $\mu$ SiM
- ▶ Mass production of components
- ▶ Rapid assembly by local users with no knowledge of microfab
- ▶ Accessories and custom components to match individual lab needs/wants

McCloskey et al., (2022) Adv. Healthcare Mater., 202200804



# Translational Center for Barrier Microphysiological Systems

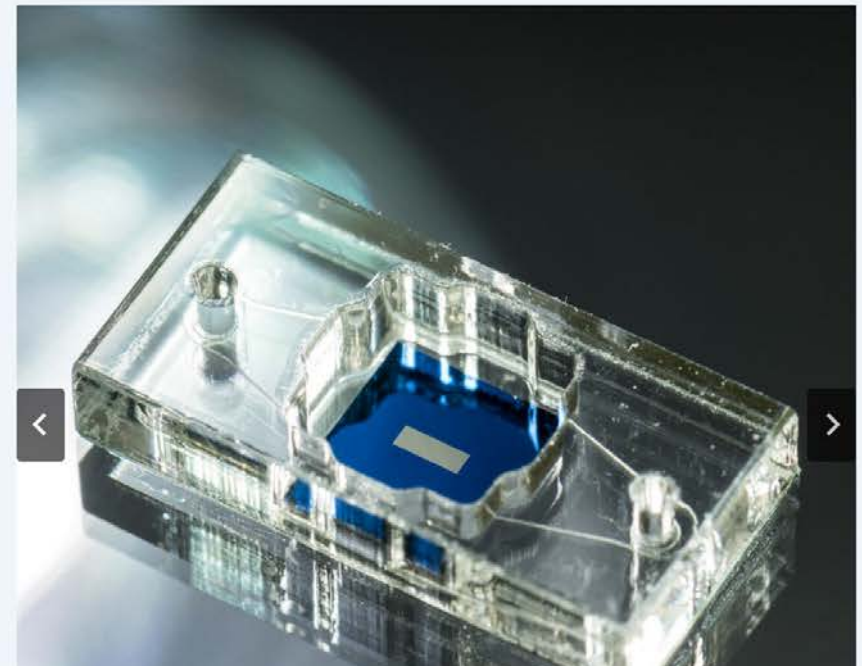
[trace-bmps.org](https://trace-bmps.org)



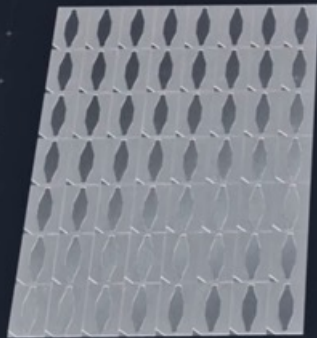
[Home](#) [Chips](#) [Membranes](#) [Sensors](#) [Models](#) [Publications](#) [Partners](#) [TraCe Services](#) [Protocols](#) [Video Gallery](#)


## TraCe-bMPS

The Translational Center for Barrier Microphysiological Systems (TraCe-bMPS) is a consortium of industry and academia developing and applying chip-based models of human tissue for both discovery and regulatory drug development. We use technologies and platforms that facilitate interactions between cells and molecules in adjacent tissue compartments, and enable in situ measurements of tissue phenotypes. Resource sharing and collaboration are a central part of the Center's mission. So if you see an opportunity to collaborate



# Assembly



ALINE

The logo for ALINE, featuring a stylized green and blue graphic element to the left of the word "ALINE" in a green, outlined font.

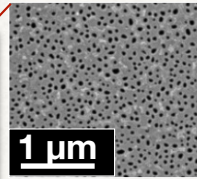
 Play video

A dark blue button with a white play icon and the text "Play video" in white.

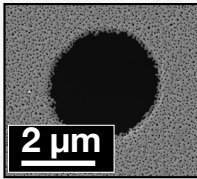
# CUSTOMIZATION THROUGH MODULARITY: MEMBRANES

APPLICATION:  
S.AUREUS INFECTION  
OF BONE

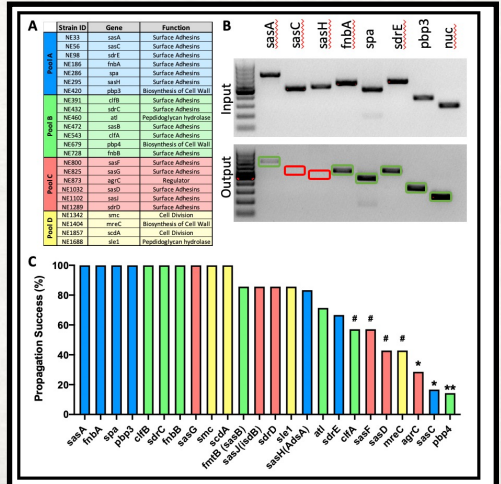
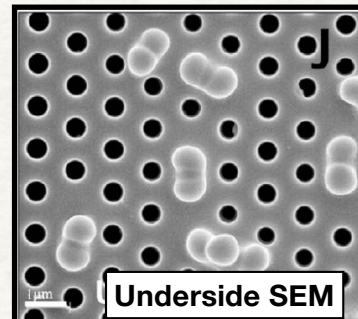
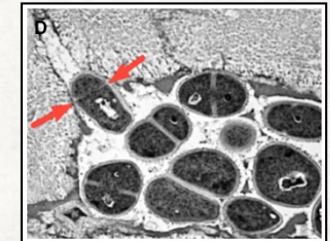
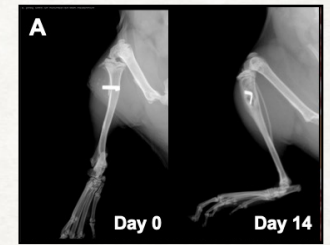
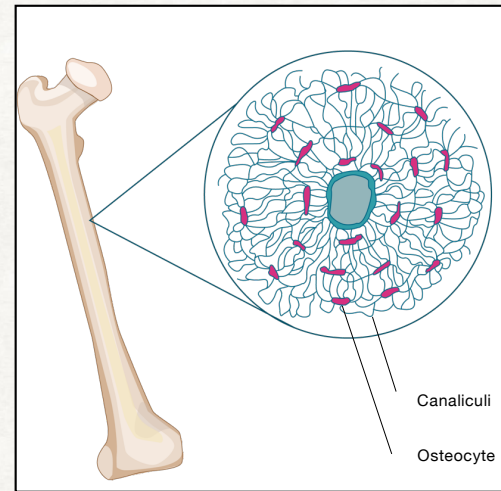
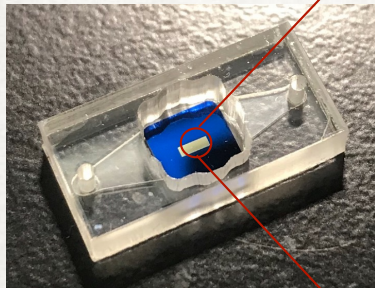
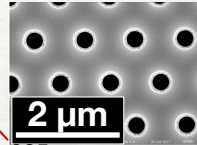
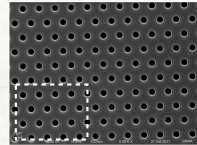
NPN: nanoporous (60 nm)



Dual Scale: nanoporous w/ 3 μm pores



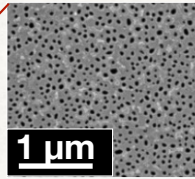
Microporous



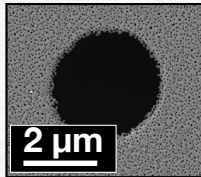
# CUSTOMIZATION THROUGH MODULARITY: MEMBRANES

APPLICATION: IMMUNE CELL TRANSMIGRATION

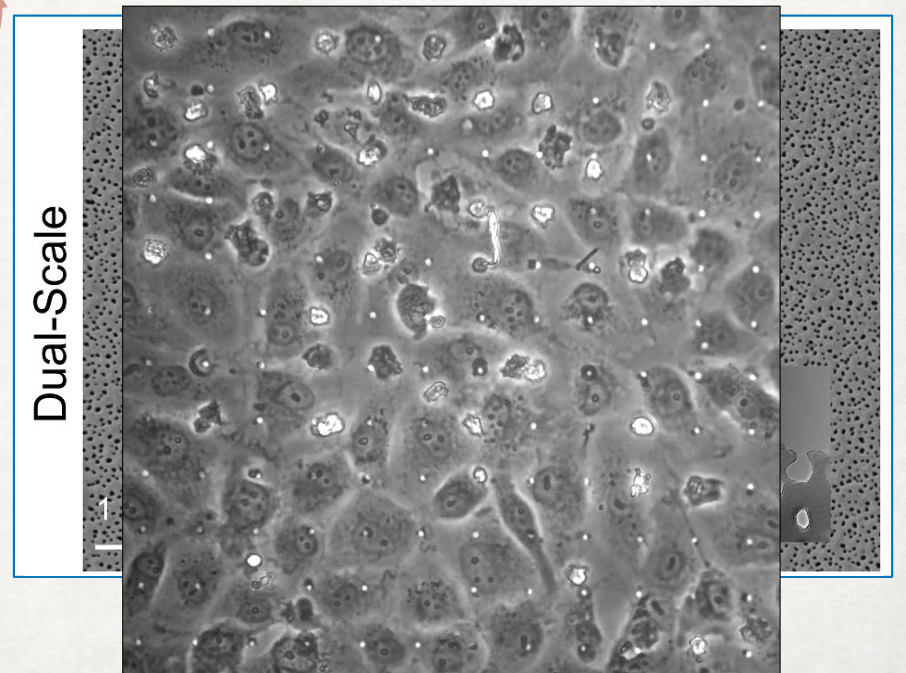
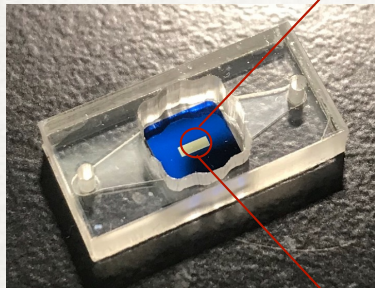
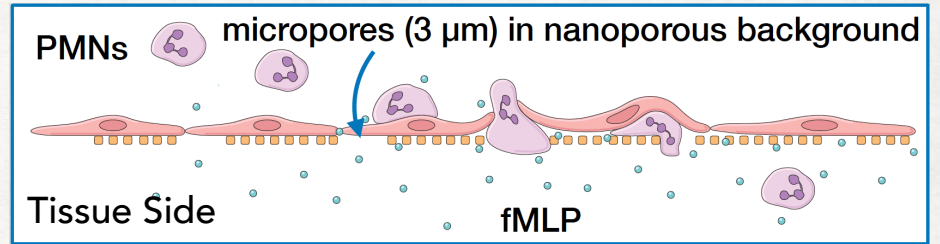
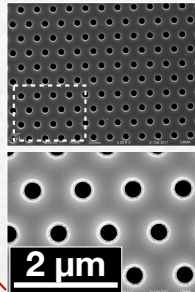
NPN: nanoporous (60 nm)



Dual Scale: nanoporous w/ 3 μm pores



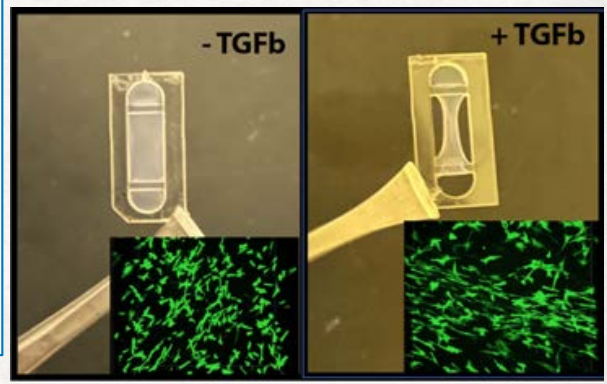
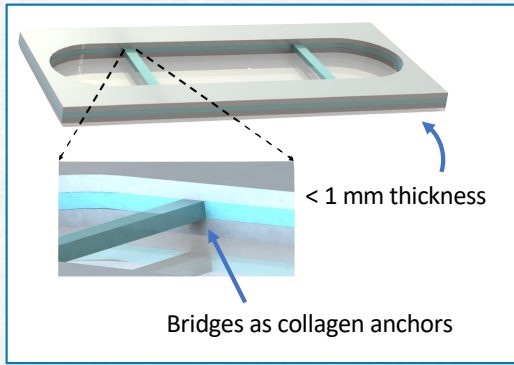
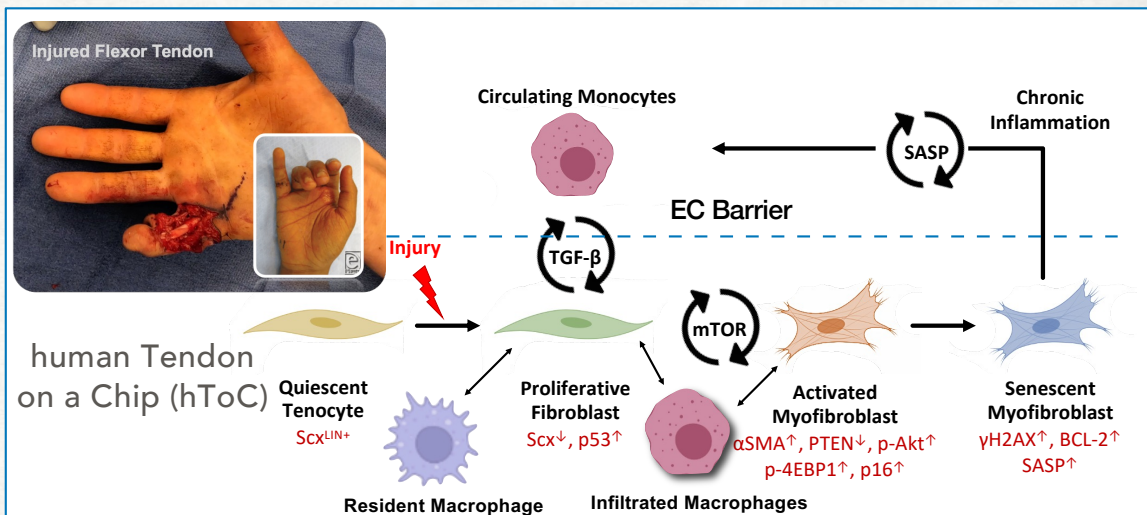
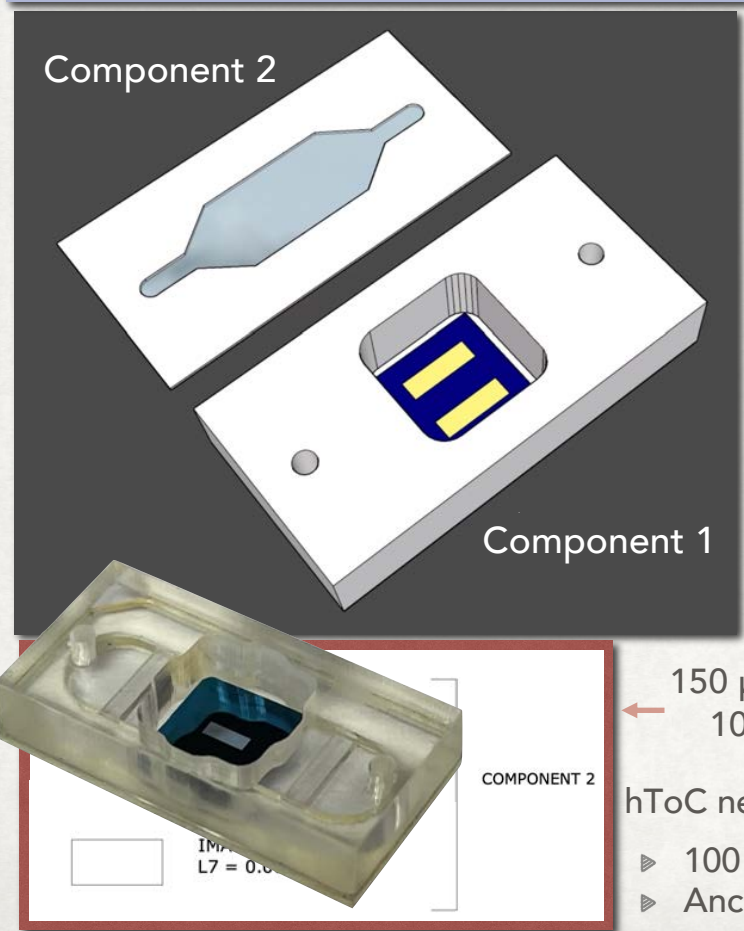
Microporous



Salminen et al., (2019) *Small* 5:e1804111

# CUSTOMIZATION THROUGH MODULARITY: COMPONENT 2

## APPLICATION: TENDON HEALING



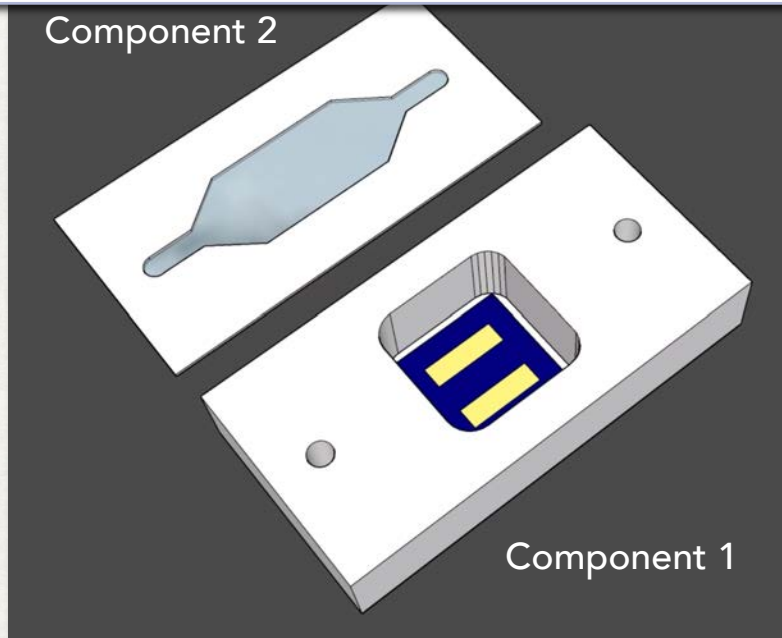
hToC needs:

- ▶ 100  $\mu$ L to support collagen hydrogel
- ▶ Anchors to support contraction by fibroblasts

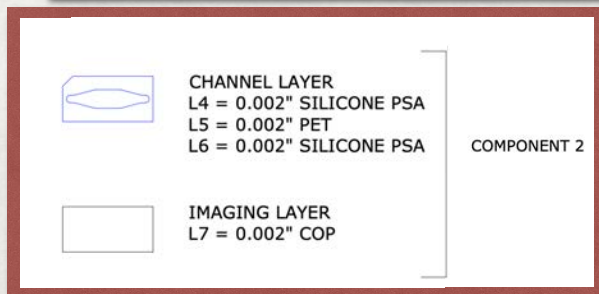
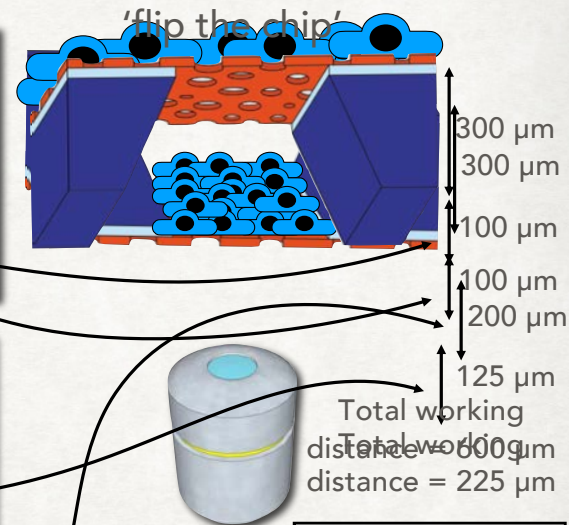
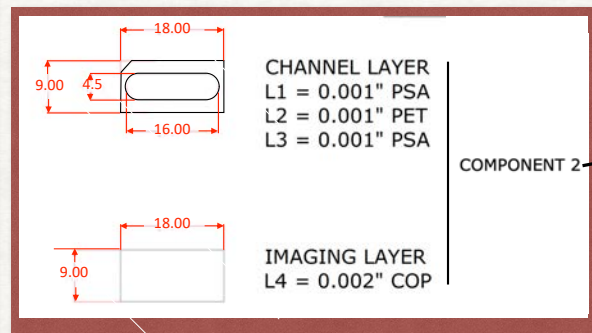
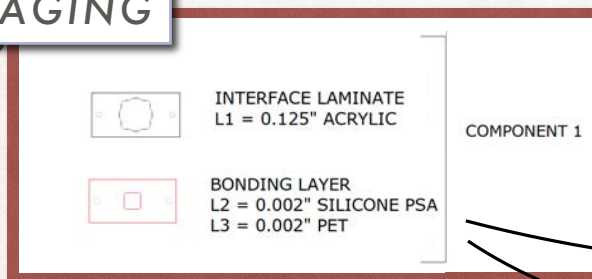
# CUSTOMIZATION THROUGH MODULARITY: COMPONENT 2

APPLICATION: HIGH RESOLUTION IMAGING

Component 2



Component 1



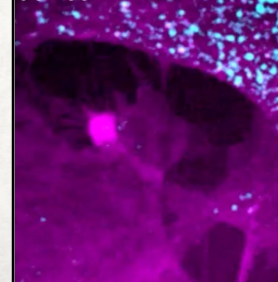
200  $\mu$ m tall  
Works with 10X - 40X

High resolution needs needs:

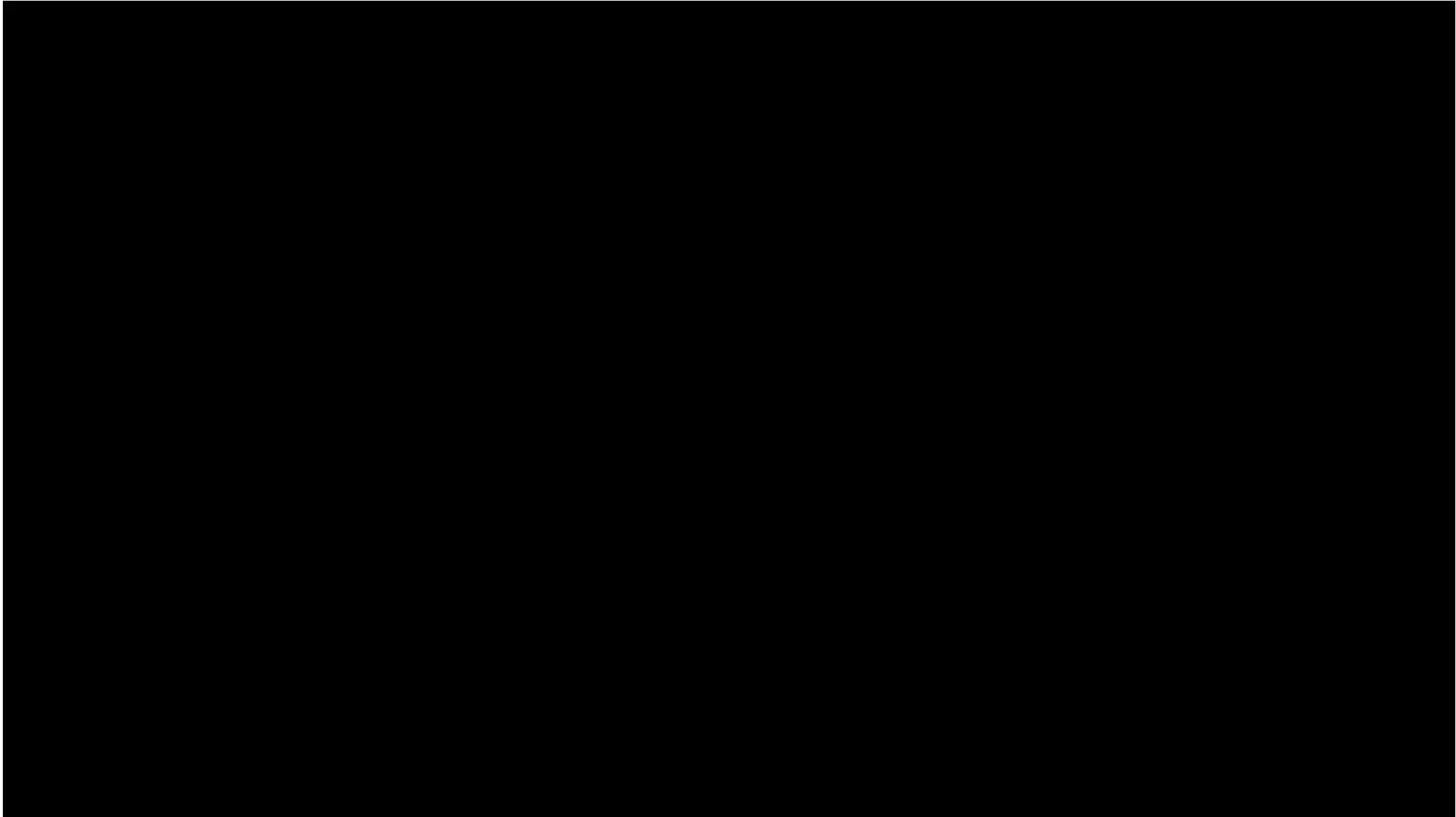
- ▶ Lower working distance needed to enable 60 - 100X imaging
- ▶ Still maintain bottom channel fluid access

- ▶ Diana Hudecz (Nielsen Lab @ Arhaus, Denmark)
- ▶ Live vesicle trafficking. 1st ever on a membrane.

2 hr pulse, 40 min chase of 0.5  $\mu$ M Alexa 647 labelled TfR antibody → only hAstro on  $\mu$ SiM device



▶ Play video



 [Play video](#)

# DESIGNED FOR MANUFACTURING (hToC EXAMPLE)

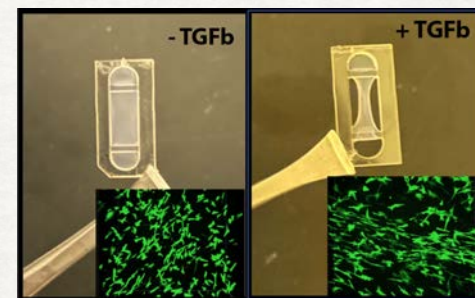
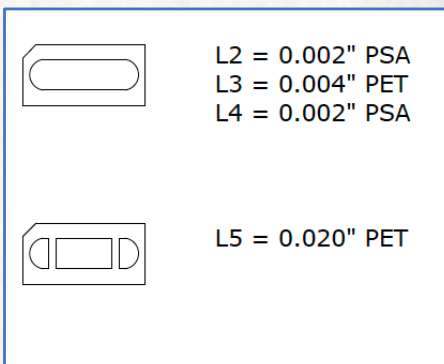
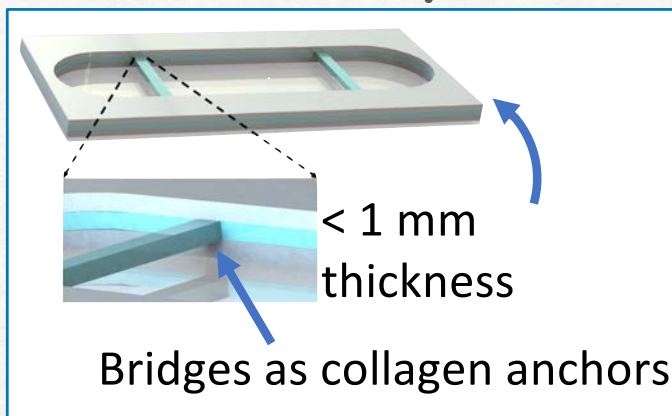
☑ DESIGN CUSTOM COMPONENT(S)

Concept → ALine Design

☑ SMALL PRODUCTION RUN

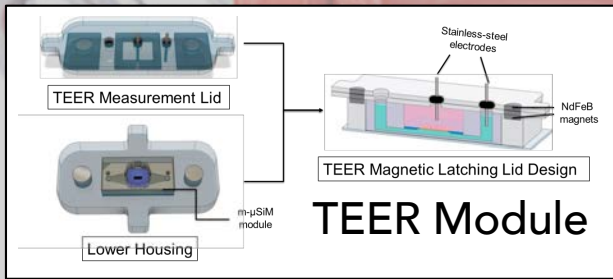
☑ TEST AND REDESIGN (IF NEEDED)

☑ LARGE PRODUCTION  
(100'S, 1000'S ... 10,000'S)



- ▶ Anchors successfully retain collagen gel with cytokine-triggered myofibroblast contraction.
- ▶ Inset shows myofibroblasts more aligned when activated

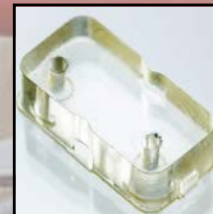
# THE $\mu$ SIM AS A MODULAR PLATFORM FOR TISSUE MODELING



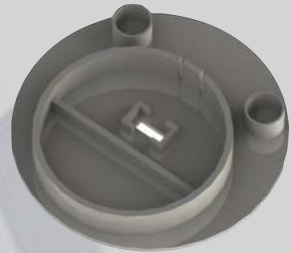
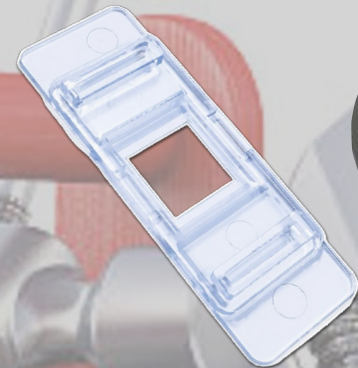
Advanced Systems



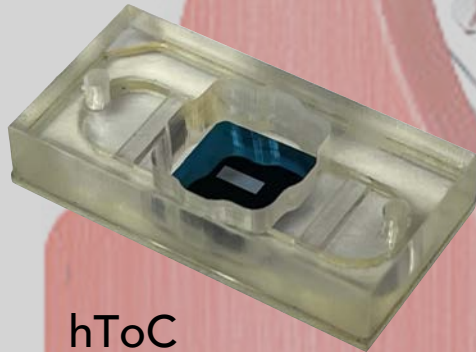
Apical Flow Insert



Basal Flow Bumpers



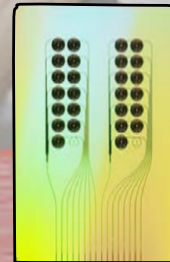
Accessories



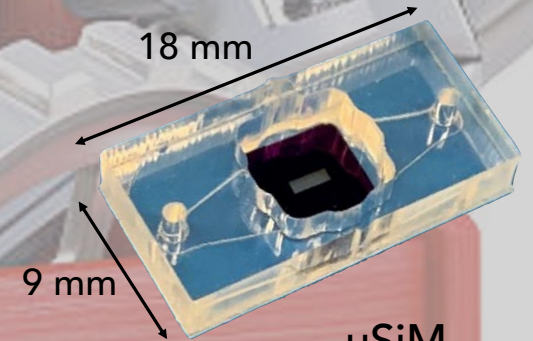
hToC  
3D Tissue Modeling w/ a Barrier



Membrane Chip



Sensor Chips (B. Miller)



$\mu$ SiM  
Barrier Modeling

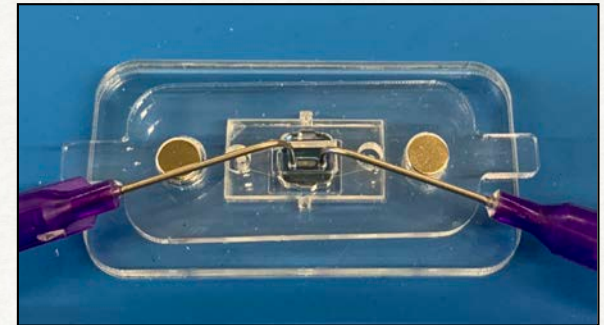
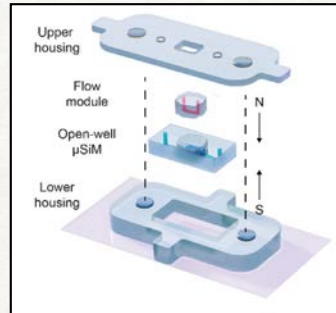
# MANUFACTURED FLOW INSERT

RESEARCH ARTICLE

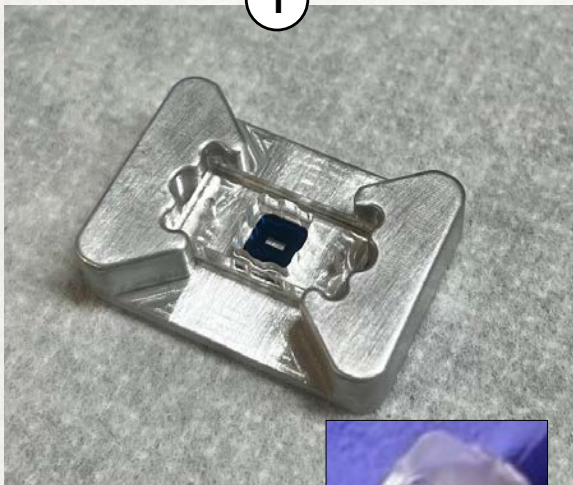
ADVANCED  
HEALTHCARE  
MATERIALS  
www.advhealthmat.de

## The Modular $\mu$ SiM Reconfigured: Integration of Microfluidic Capabilities to Study In Vitro Barrier Tissue Models under Flow

Mehran Mansouri, Adeel Ahmed, S. Danial Ahmad, Molly C. McCloskey, Indranil M. Joshi, Thomas R. Gaborski, Richard E. Waugh, James L. McGrath, Steven W. Day, and Vinay V. Abhyankar\*



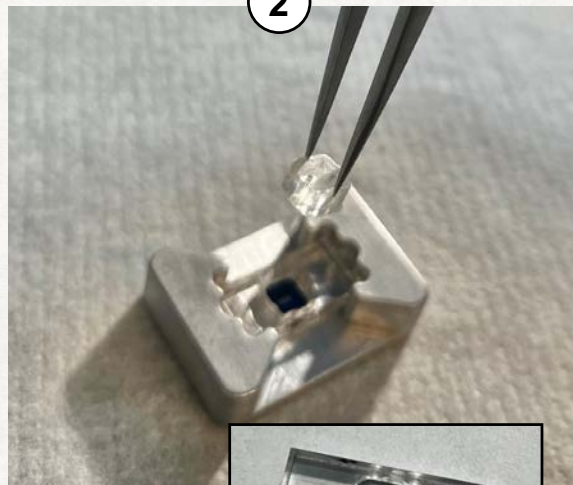
1



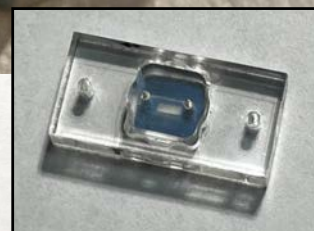
Assemble  $\mu$ SiM and place in jig



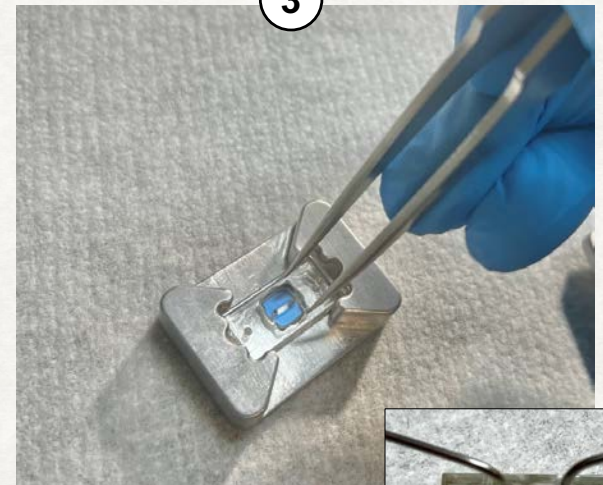
2



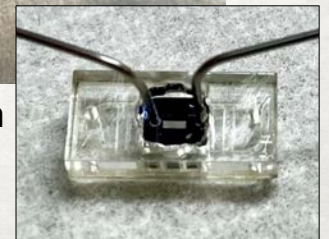
Grab flow insert with tweezers on smooth edges



3



Align flow insert with open well and gently adhere to membrane with tweezers



# FLOW BUMPERS FOR RELIABLE BASAL FLOW

Contents lists available at ScienceDirect

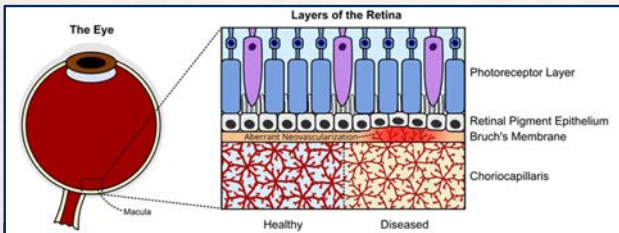
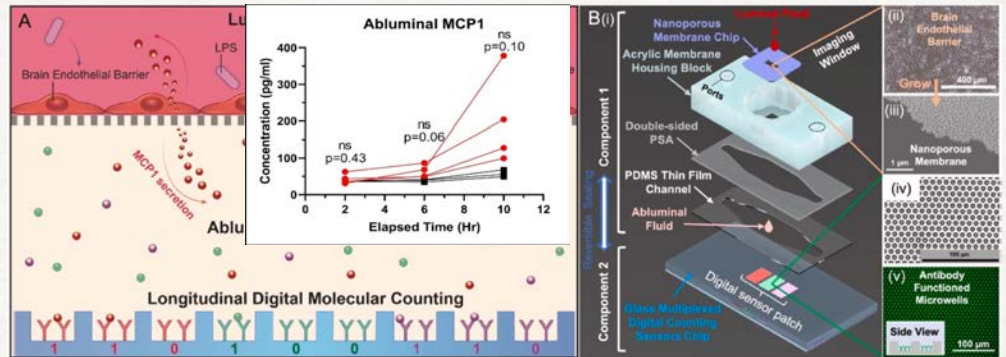
2023

Biosensors and Bioelectronics

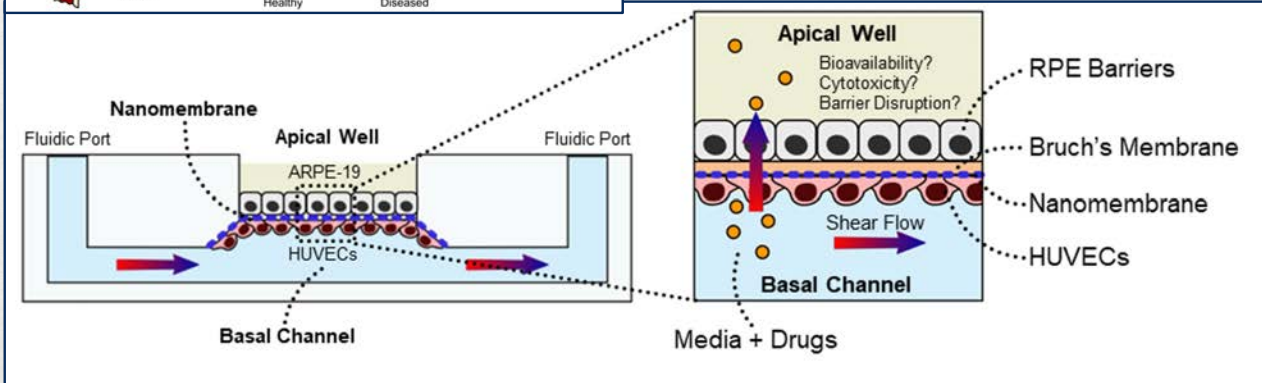
journal homepage: [www.elsevier.com/locate/bios](http://www.elsevier.com/locate/bios)

A tissue chip with integrated digital immunosensors: In situ brain endothelial barrier cytokine secretion monitoring

Shiuan-Haur Su<sup>a</sup>, Yujing Song<sup>a</sup>, Andrew Stephens<sup>a</sup>, Muyu Situ<sup>c</sup>, Molly C. McCloskey<sup>g</sup>, James L. McGrath<sup>g</sup>, Anuska V. Andjelkovic<sup>f</sup>, Benjamin H. Singer<sup>c,d,h,\*</sup>, Katsuo Kurabayashi<sup>a,b,d,\*</sup>



- ▶ Multiple projects appeared that required basal flow.
- ▶ Howard Su's methods proved unreliable in different hands.
- ▶ Inspired by the flow insert ... The manufactured flow bumper.



# ADVANCED SYSTEMS

## TEER and Impedance (Vinay Abhyankar @ RIT)

bioRxiv preprint doi: <https://doi.org/10.64898/2026.03.08.703312>; this version posted March 10, 2026. The copyright holder for this preprint (which was not certified by peer review) is the author/funder, who has granted bioRxiv a license to display the preprint in perpetuity. It is made available under aCC-BY-ND 4.0 International license.

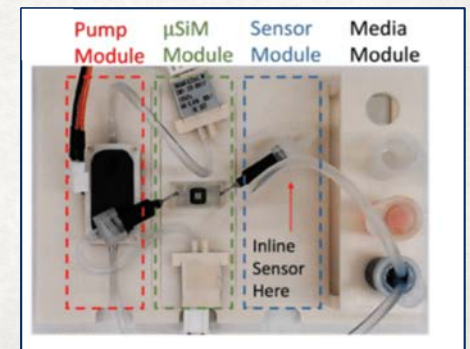
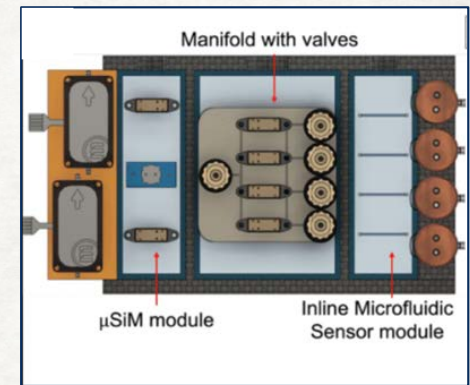
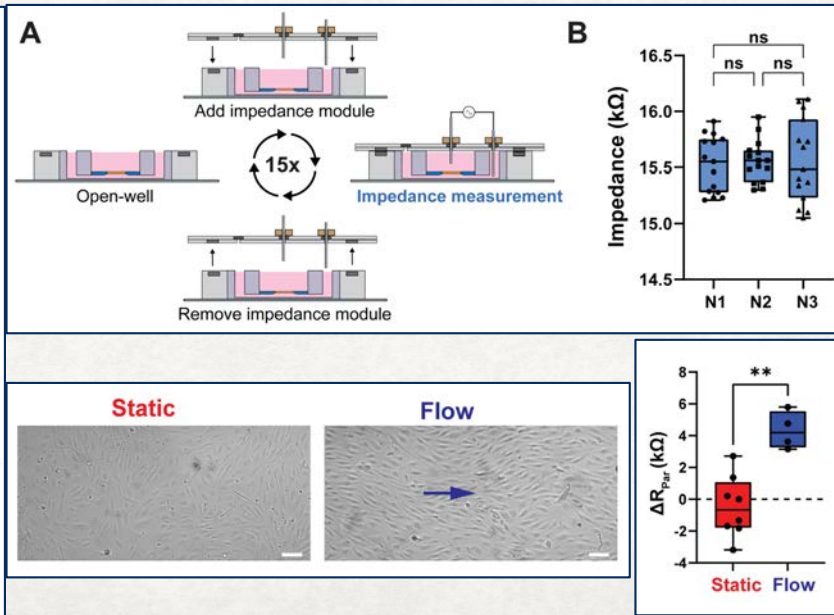
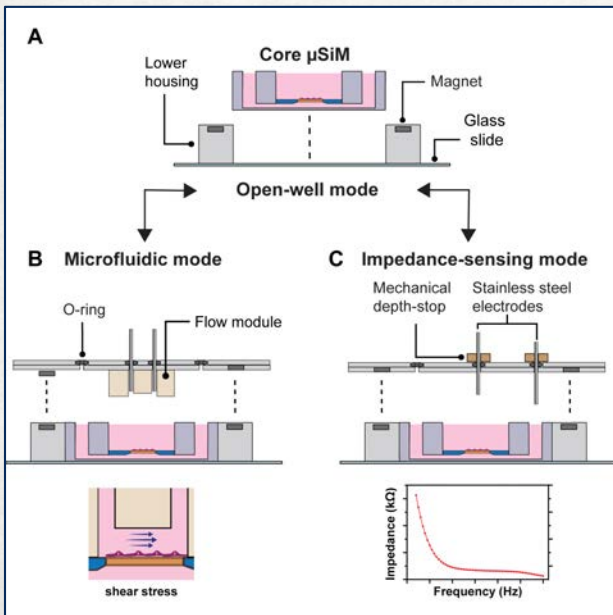
### Modular Integration of Impedance Sensing for Real-Time Assessment of Barrier Integrity

Sami Farajollahi<sup>1\*</sup>, Mehran Mansouri<sup>1\*</sup>, Dinindu De Silva<sup>1</sup>, Meng-Chun Hsu<sup>1</sup>, Kaihua Chen<sup>3</sup>, Aidan Hughes<sup>1</sup>, Poorya Esmaili<sup>1</sup>, Kritika Goyal<sup>2</sup>, Steven W. Day<sup>1</sup>, James L. McGrath<sup>3</sup>, and Vinay V. Abhyankar<sup>1†</sup>



## Multifunctional Fluidics

Aditya Raghunandan  
@ UMichigan  
IntegraSiM



# What we do now ...

## Trace Services

## Eventually ...



### USERS & PROJECTS

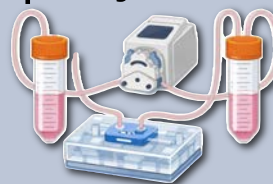
- ~20 active labs
- >30 active projects
- >10 pipeline projects

- Internal academic labs (UR)
- External academic labs (multi-institutions)
- Industry and Pharma



### CHIP PRODUCTION AND DISTRIBUTION

5000+ chips per year



- Multiple formats
- Lot-level quality assurance
- Accessories for fluidics, imaging, measurements
- Packaging, tracking and distribution
- Design and simulation files
- User on-boarding and training
- Protocol sharing (most are not QS grade)
- Technical Notes (blog)



### QUALITY SYSTEM DEVELOPMENT

~50+ SOPs

Multi-site reproducibility

- Quality system development
- Regulatory-ready SOPs
- Change control & version management
- Centralized data stewardship & analytics
- Reproducibility testing infrastructure
- Regulatory engagement (ISTAND)
- MPS/NAMS statistical services

# How do we it ...

# TraCe-bMPS.org



## Translational Center for Barrier Microphysiological Systems

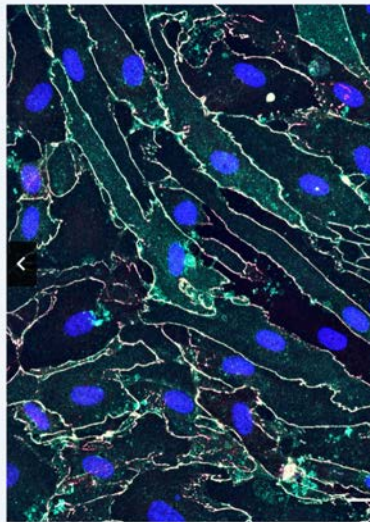
[Home](#) [Chips](#) [Membranes](#) [Sensors](#) [Models](#) [Publications](#) [Partners](#) [TraCe Services](#) [Protocols](#) [Video Gallery](#)

[Blog](#) [Calculators](#) [Shop](#) [Projects](#) [Resources](#) [Partners](#) [Executive Trackers](#) [TraCe Protocols](#)

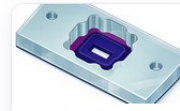
## TraCe-bMPS

The Translational Center for Barrier Microphysiological Systems (TraCe-bMPS) is a consortium of industry and academia developing and applying chip-based models of human tissue for both discovery and regulatory drug development. We use technologies and platforms that facilitate interactions between cells and molecules in adjacent tissue compartments, and enable in situ measurements of tissue phenotypes. Resource sharing and collaboration are a central part of the Center's mission. So if you see an opportunity to collaborate, please inquire.

[Contact TraCe Services](#)



### Featured protocols



**Assembling  $\mu$ SIM Top Component with Membrane Chip**

Assembly • Microfluidics

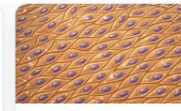
[View protocol →](#)



**Assembling  $\mu$ SIM Devices with Flow Insert**

Apical Flow • Flow Insert

[View protocol →](#)



**Endothelial Cell Growth and Maintenance in the  $\mu$ SIM with a Flow Insert**

Cell Culture • Cell Viability

[View protocol →](#)



**Seeding Cells in Flow Insert - NPN Version**

Seeding Cells • Flow Insert

[View protocol →](#)

Home / Shop

## Shop

Quality control for NPN, Microporous, and Dual Scale can be found by clicking on the desired membrane type.

Showing 1–40 of 46 results

Default sorting



NPN 1 Slot

[View Product](#)



NPN 2 Slot

[View Product](#)



NPN 4 Slot

[View Product](#)



3  $\mu$ m Dual Scale - Low Porosity

[View Product](#)



$\mu$ SIM-CA Nonporous Membrane Assembled Device

[View Product](#)



$\mu$ SIM-CA 0.5  $\mu$ m Membrane Assembled Device

[View Product](#)



$\mu$ SIM Component 1

[View Product](#)



$\mu$ SIM Component 2

[View Product](#)



$\mu$ SIM High Resolution

[View Product](#)



hToC Channels

[View Product](#)



hToC Reservoir

[View Product](#)



Component 2 - PIC

[View Product](#)

Home / Blog

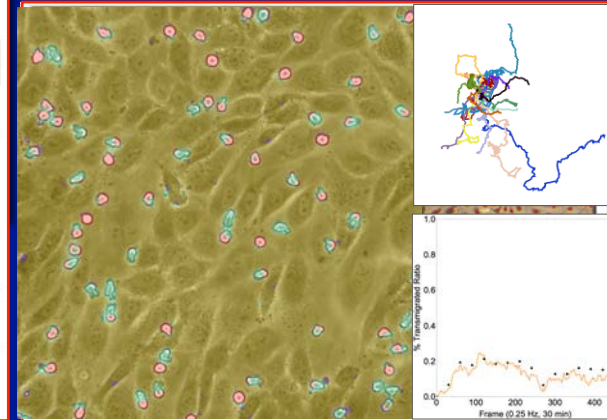
## Macrophage Culture in the hToC

Posted on December 9, 2025 by [Emily Reitz](#) — 2 Comments ↓

Introduction I recently established the feasibility of digesting cells out of the collagen I gels in the hToC bottom channels and reservoirs to use for flow cytometry. This involved using collagenase I and dispase II to digest fibroblasts and macrophages ...

[Read more ↓](#)

Posted in TRACE



[▶ Play video](#)

# BUILD YOUR OWN TISSUE CHIP

## 🔑 1. Define Biomedical Context

Identify the relevant tissue unit (e.g., BBB, alveolus) and pathophysiological hallmarks (e.g., barrier leak, edema), and clinical benchmarks (biomarkers, imaging, PK/PD) to emulate.

## 💡 2. Formulate the Purpose within the disease context: disease mechanism, Drug MOA, toxicity, dose

State what the model is for: probing a disease mechanism, a drug's MOA, a toxicity, or a dose response. Together with the disease context, the purpose defines your **1+2 = Context of Use**.

## 🧪 3. Engineer the Microenvironment

What cells are needed and how will you source them (primary or iPSC). Start with a minimum. What matrix materials (eg. collagen IV, laminin) are required? Key biophysical inputs (eg. shear, stretch) or biochemical (eg. cytokines, oxygen)? **START WITH A CARTOON**.

## 📊 4. Specify Functional Inputs and Outputs

Define dynamic inputs (e.g., LPS) or immune invasion. Timescale? Kinetics? How is phenotype determined and when (TEER, permeability), molecular (cytokines, RNAseq), and structural (tight junctions). Define quantitative metrics and expectations for resolution, dynamic range, values at baseline, test conditions.

## 🏗️ 5. Design a Chip that is 'fit for purpose' **Don't begin here!**

Choose appropriate architecture (e.g., dual-channel, stacked membranes), with input/output ports, sensors (TEER, imaging), and multiplexable sampling. Enable automation and scaling.

First Draft

Simultaneous Equations



# BRAIN INJURY FOLLOWING SYSTEMIC INFLAMMATION

## MODELING SYSTEMIC INFLAMMATION LEADING TO BRAIN INJURY GUIDEPOSTS AND INSPIRATIONS

1) , patients who may have been previously resilient to their underlying neuropathology, commonly experience an abrupt worsening of cognitive impairment after hospitalization for critical illness." - Ben Singer, MD (U. Michigan)

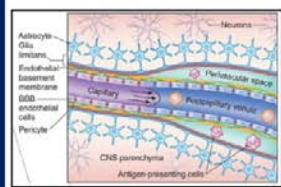
Many scenarios where 'cytokine storm' accelerates neurodegenerative disease: 1) Sepsis (A. Pietropaoli); 2) surgery in older adults (N. Terrando); 3) acute lung injury (H. Gelbard); ; 4) Immunotherapies (CAR T; bispecific mAbs - M. Kim).

Age is a risk factor for brain injury in each case

Leukocytes as an agent of brain injury ...

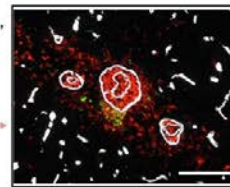
Trzeciak, et al. J Immunol. 2019. 203(11):2979-2988  
Andonegui, et al. (2018). JCI Insight 3(9): e99364.

Leukocytes enter the brain at the post-capillary venule ... which is two barriers in series



Engel et al., 2017. Nat Immunol, 18: 123-31.

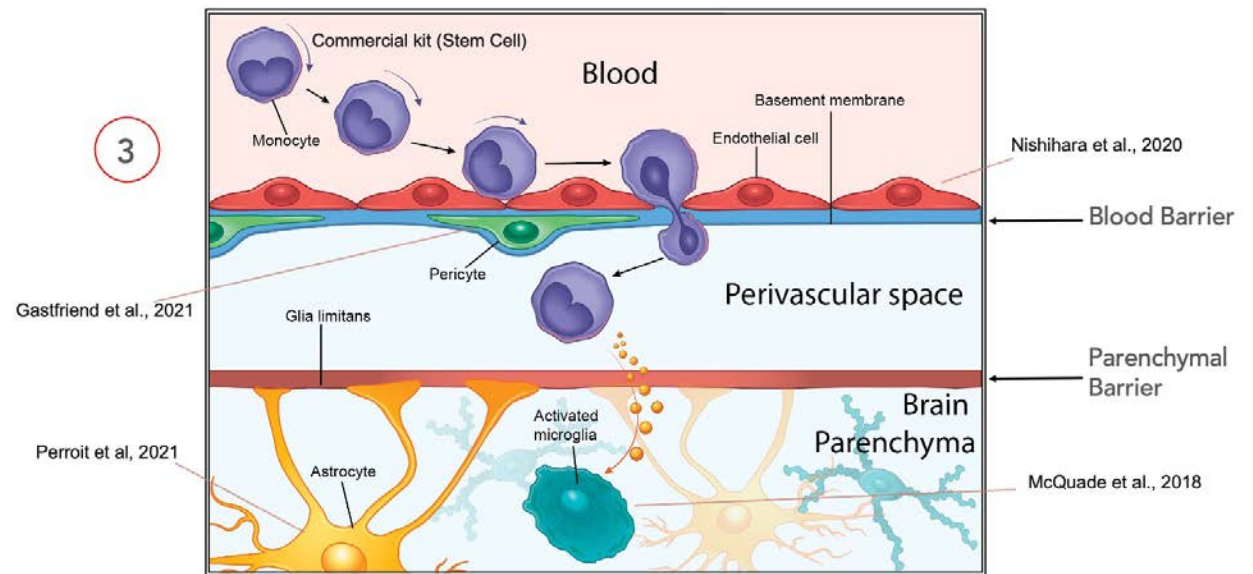
Song, C. et al., Cell Rep 10(7) (2015) 1040-54.



Cunningham and Hennessy *Alzheimer's Research & Therapy* (2015) 7:33

systemic inflammatory events

## DIFFERENTIATION OF iPSCS for the $\mu$ SiM - pcNVU



[1] A. McQuade, Mol Neurodegener 13(1) (2018) 67

[2] B.D. Gastfriend, Curr Protoc 1(1) (2021) e21

[3] H. Nishihara, B.D. FASEB. J. 34(12) (2020) 16693-16715

# ANTI-INFLAMMATORY STRATEGIES FOR SCARLESS TENDON REPAIR

Monocyte invasion from a model circulation in the human tendon on a chip (hToC)  
from Linares et al., (2025) Scientific Reports 15:3227



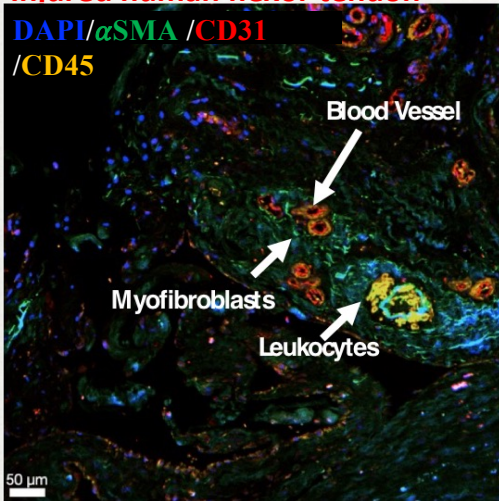
w/ Hani Awad

CENTER for  
MUSCULOSKELETAL  
RESEARCH

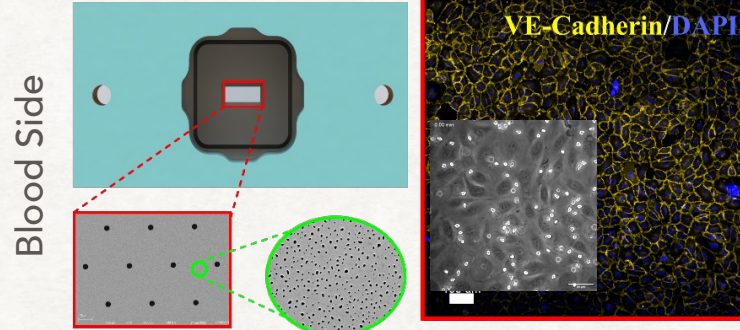


# Human Tendon-on-a-Chip (hToC) as a Model of Tendon Injury and Repair

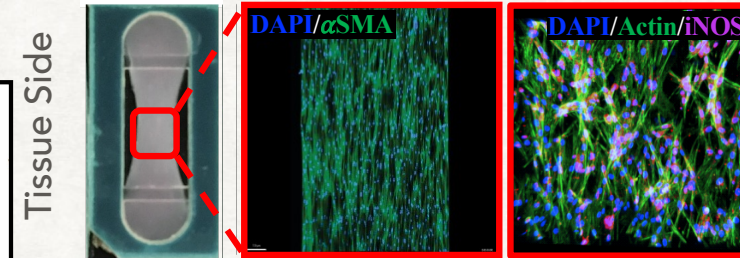
## Injured human flexor tendon



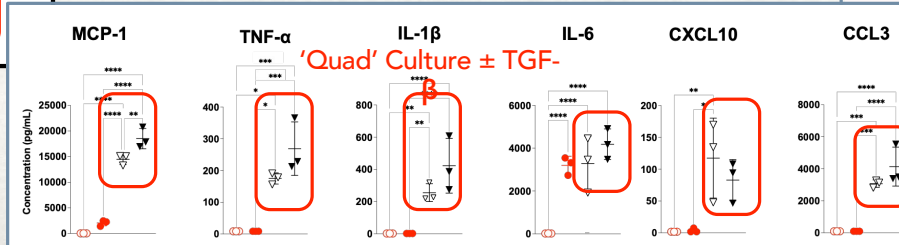
## Modeling Leukocytes/EC interactions



## Modeling myofibroblast activation

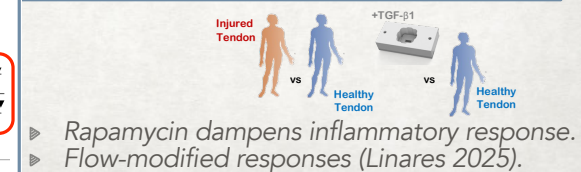
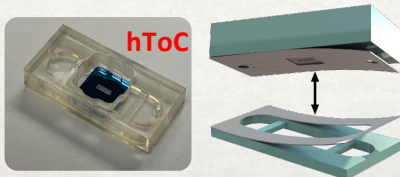
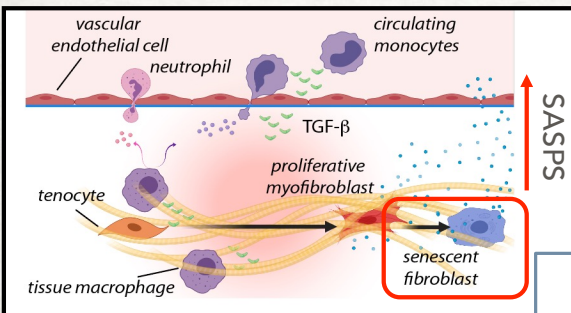
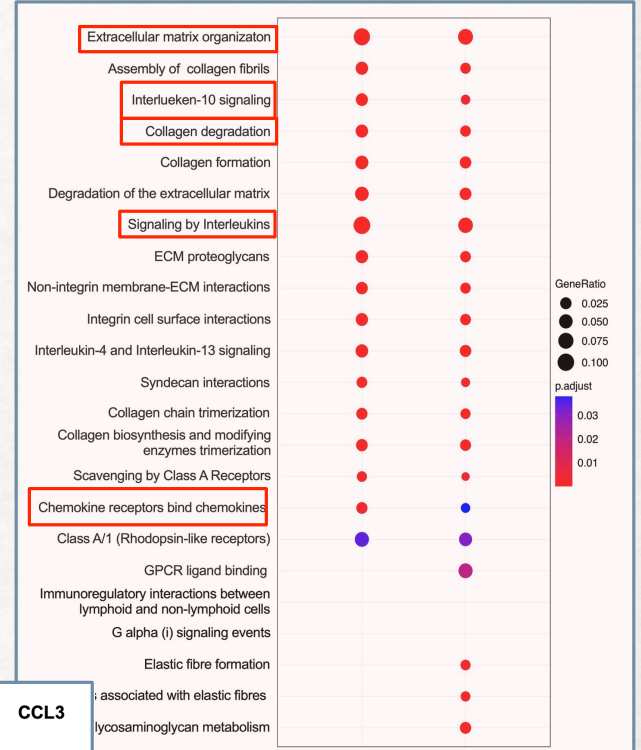


## Modeling inflammatory secretions

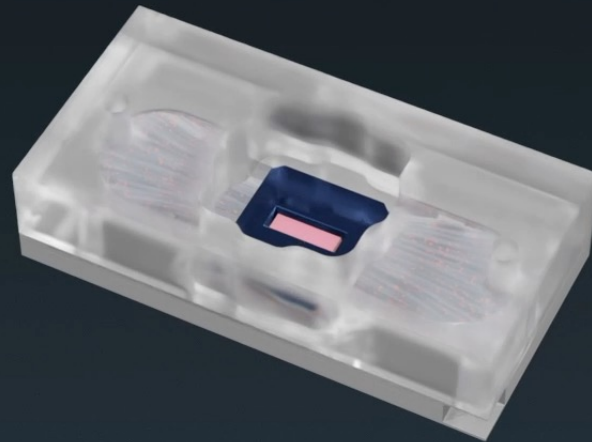


1. Ajalik, R.E. et al. *Adv Healthc Mater*, 2025. 14:e2403116.  
 2. Linares et al., (2025) *Scientific Reports* 15:3227

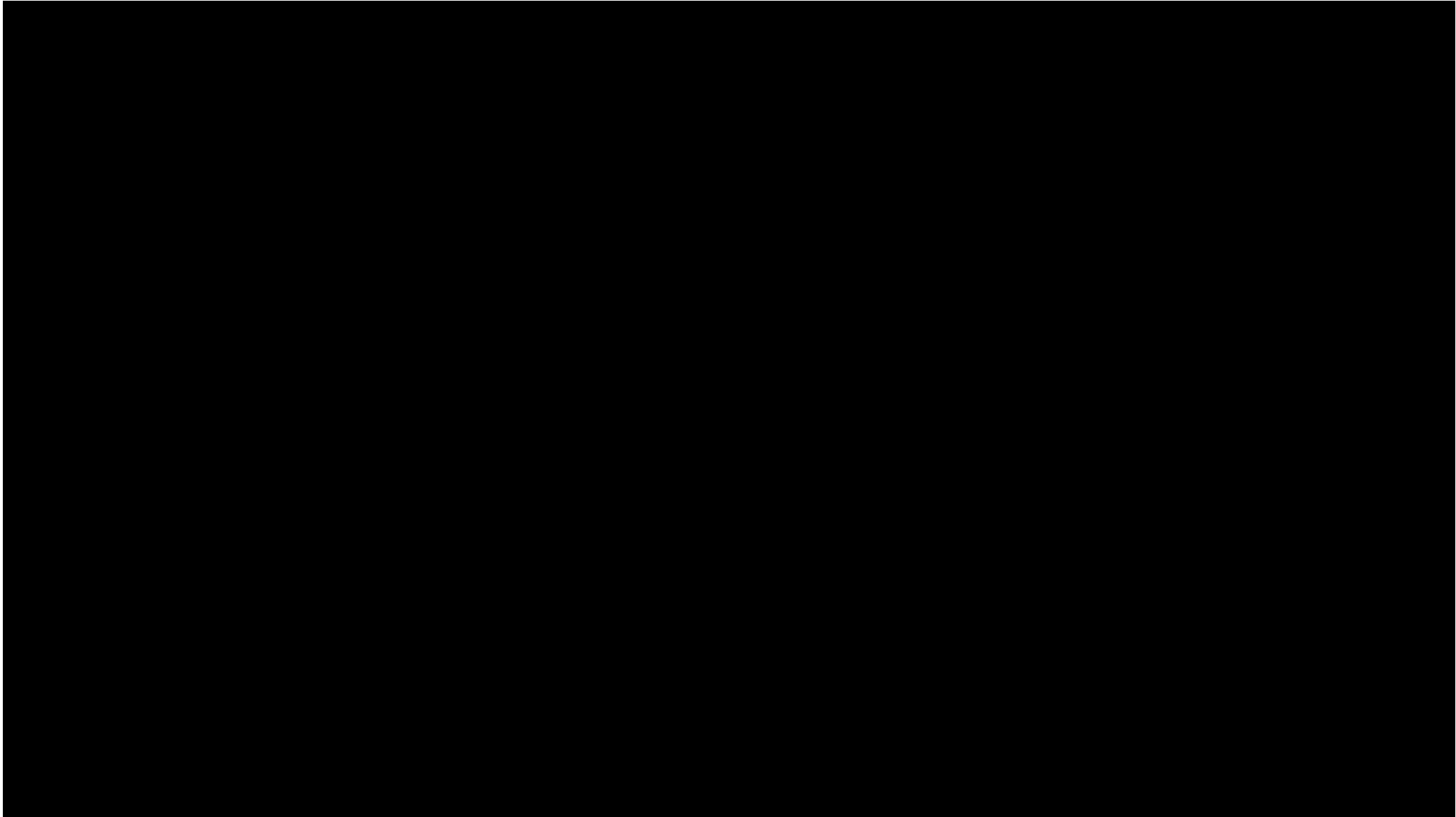
## Modeling gene transcription (RNA-Seq)



## Human Tendon-on-a-Chip (hToC)



[▶ Play video](#)



 [Play video](#)

***Your Turn!***