



CAPRA
BIOSCIENCES

Unlocking Cost-Competitive Biomanufacturing through Computational Modeling of Complex Fluid Dynamics

Dr. Andrew Magyar, Co-Founder and CTO

THE PROBLEM

America Can't Make What It Needs.

The U.S. depends on China and other foreign nations for the vast majority of its active pharmaceutical ingredients, specialty chemicals, and critical industrial feedstocks. When supply chains break — as they did during COVID, and continue to during geopolitical tensions — there is no domestic fallback.

Even when the will exists, the economics don't work. Traditional chemical manufacturing and fermentation require massive capital, years of build-out, and single-product facilities. U.S. companies can't compete on cost against entrenched foreign producers using legacy methods.

Cargill / NatureWorks PLA

\$1B+ invested. 20+ years. Still a single facility limited to one polymer. Sold at a loss.

U.S. Amino Acid Production

Virtually zero domestic production. >95% imported from China. FDA shortages rising year over year.

By the Numbers

87%

of U.S. API facilities are located overseas, predominantly in China and India

323

active FDA drug shortages — the highest in a decade, driven by fragile foreign supply chains

\$200B+

annual U.S. spend on imported specialty chemicals — with rising costs and declining reliability

0

domestic modular biomanufacturing platforms for on-demand chemical production at scale

New bioreactor designs, new organisms, and new feedstocks are necessary for the bioeconomy to succeed.

Past



Today

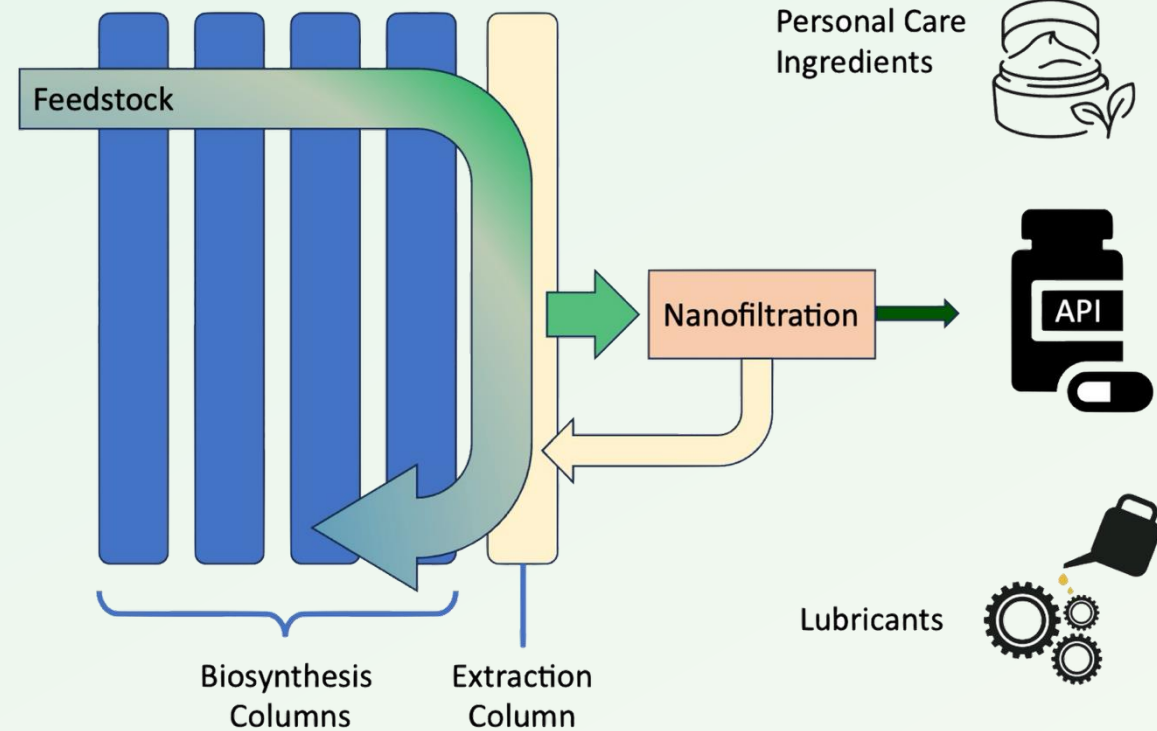


Future



Modular, scalable continuous bioreactors.

Scalable bioproduced APIs,
lubricants and other chemical
ingredients from diverse feedstocks



- Less capital intensive
- Locally-sourced feedstocks
- Continuous process

- Integrated downstream process
- Modular scaling

Design elements dramatically influence performance

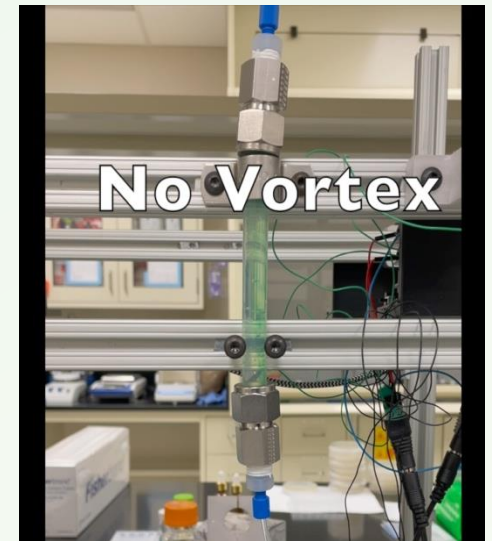
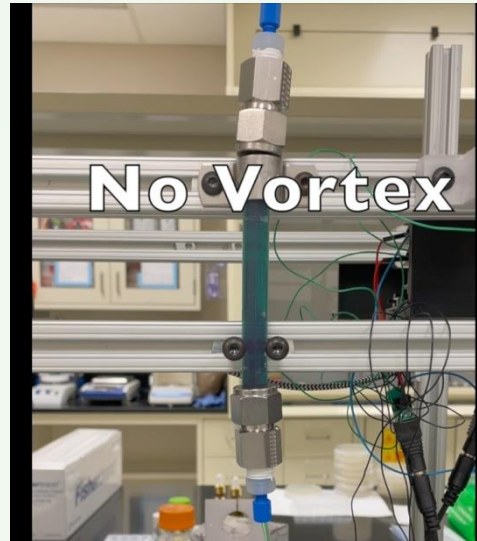
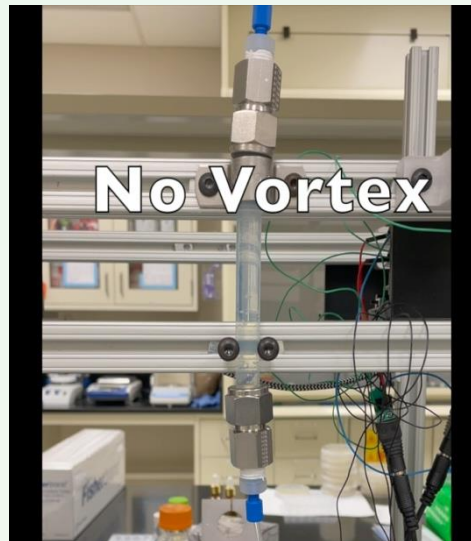
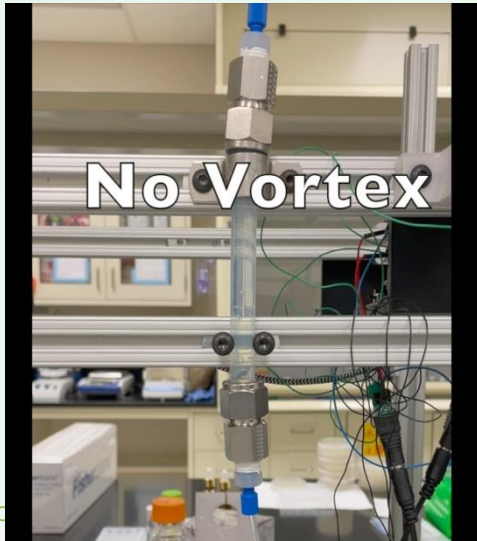
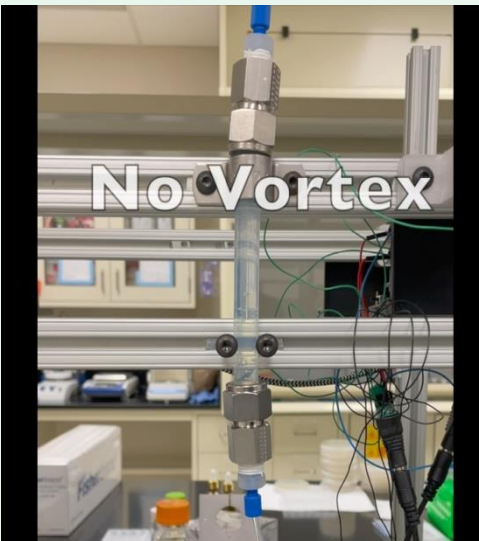
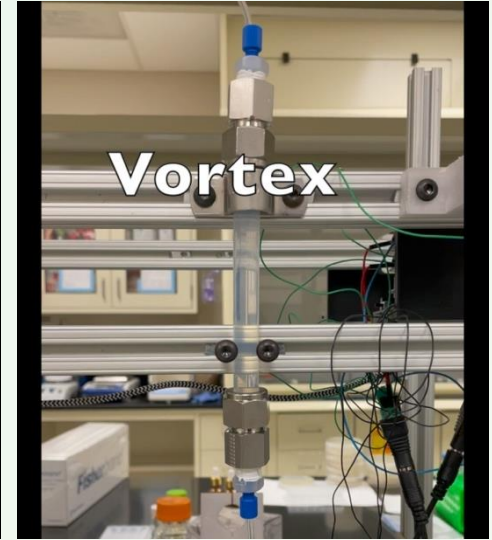
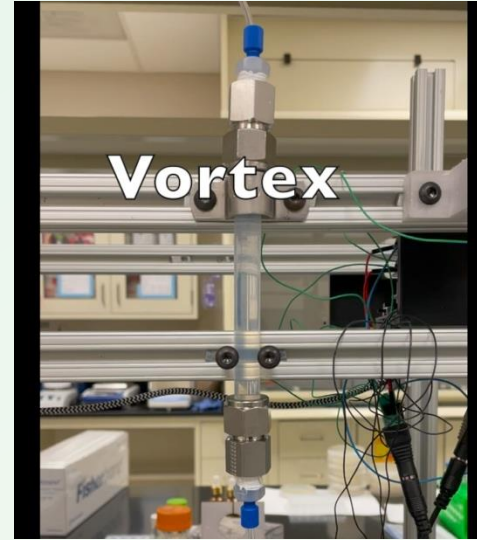
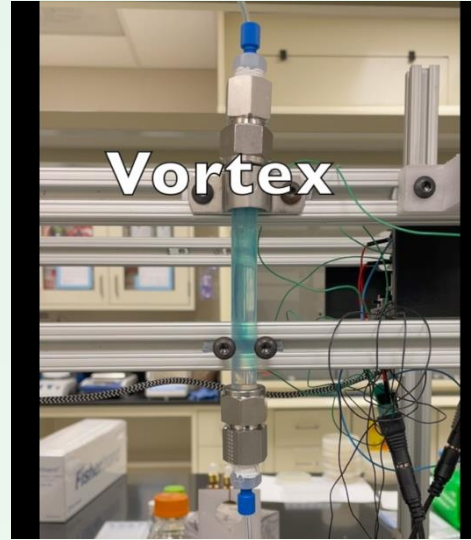
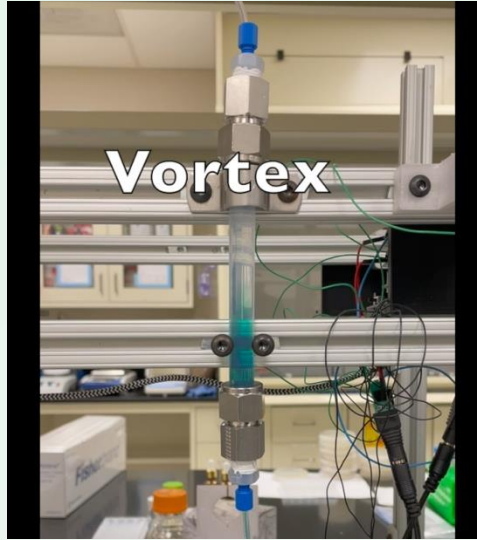
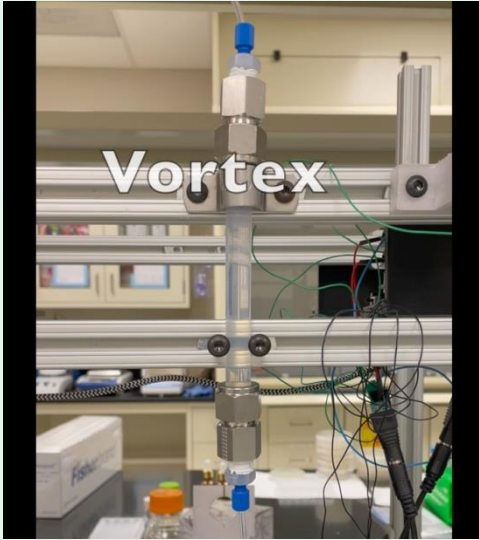
T = 0

T = 20 s

T = 60 s

T = 300 s

T = 800 s



Bioreactors are complex.

Multiscale models leveraging high performance computing can enable transformational improvements in bioreactor designs.

Challenge: Discrete element models are too computationally intensive to



Cells

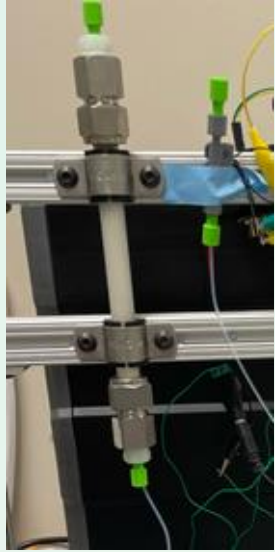
Feedstock and support solids

Growth medium

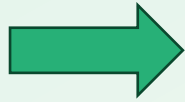
Extraction solvent

Aeration

Solution: A multi-scale computational model to of a bioreactor



10 – 30 mL reactor



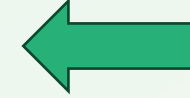
Directly model small scale reactors using **discrete element models (DEM)**

Every particle modeled directly



Use **particle-in-cell (PIC) models** to model larger reactors

Particles interact through averaged grid fields



Use small-scale DEM models to validate PIC



55 L reactor



Ishan Shrivastava, PhD, Co-PI
Research Scientist, Applied Mathematics and Computational Research Division
Lawrence Berkeley National Lab

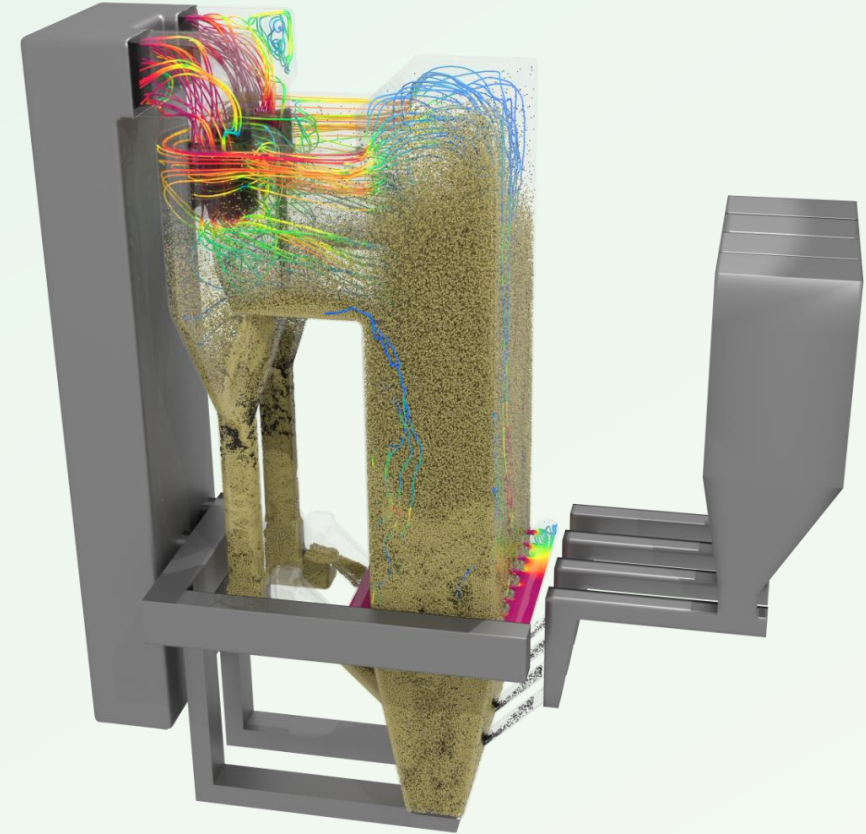


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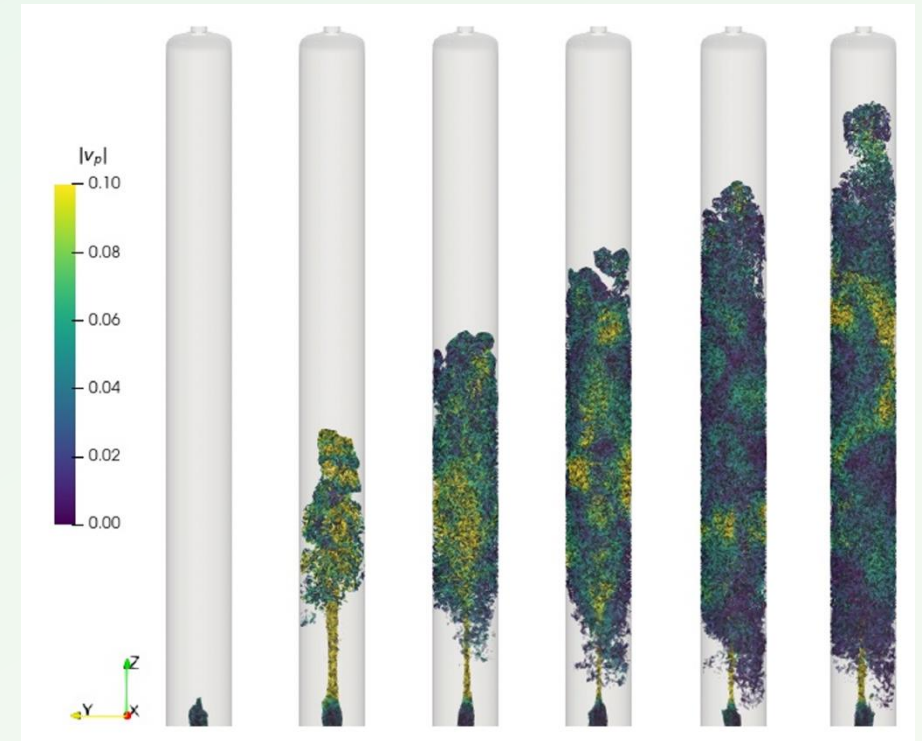
- Code developed to provide exascale computing-capable complex fluid dynamics simulations
- A fluid solver providing both CFD-DEM and PIC code
- Designed for simulation of gas-solid particle flows

 MFIXExa

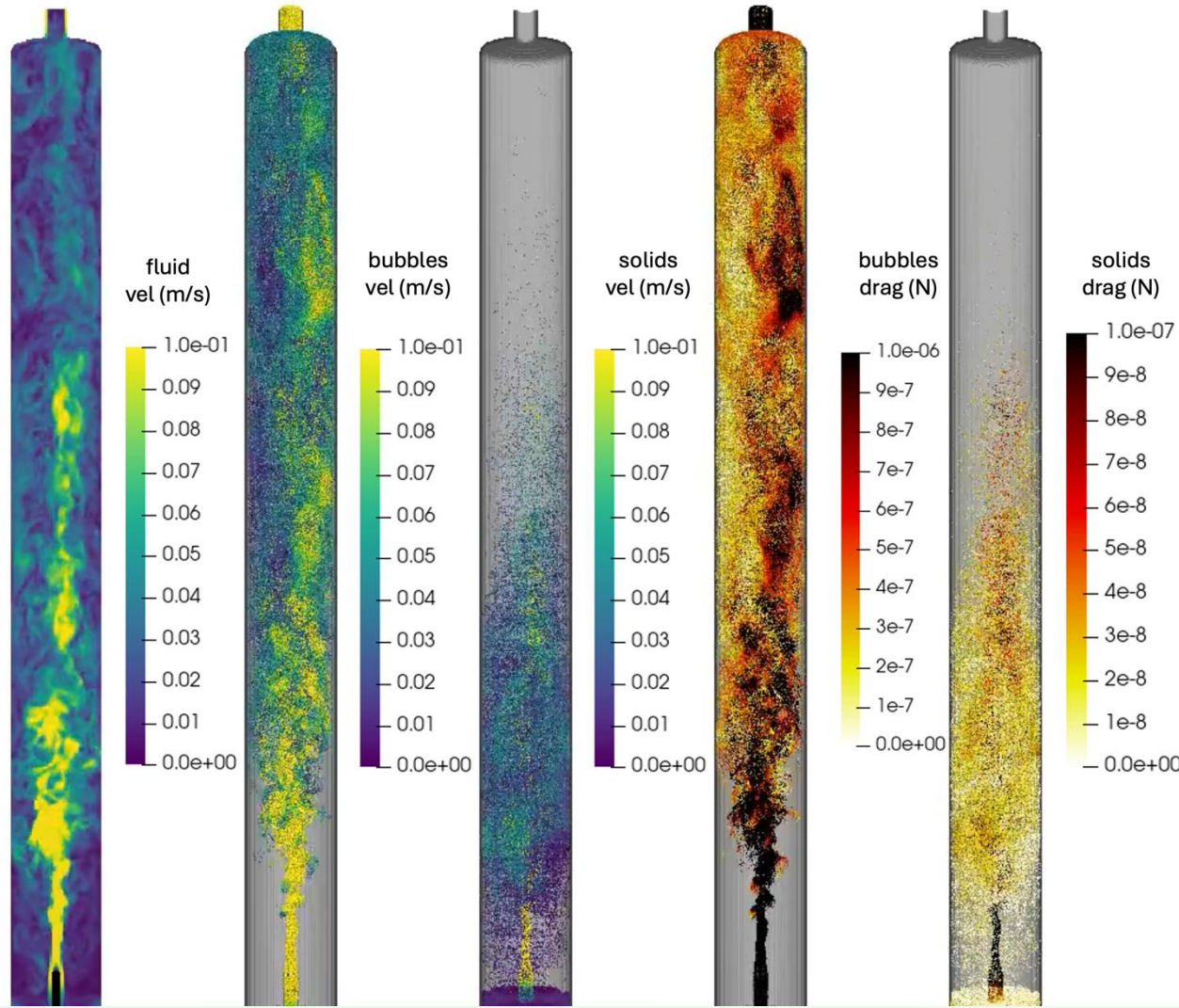
Example PIC simulation from MFIX
<https://mfix.netl.doe.gov/products/mfix/>

Developed new numerical methods in **MFIX-Exa** to enable the simulation of the liquid-gas-solid dynamics in Capra's industrial-scale bioreactors

- Implemented **virtual force models** for accurate light-particle (air bubble) dynamics in dense fluids
- Incorporated **fluid-mediated lift forces** on rising bubbles, improving prediction of bubble aggregation and column behavior
- Enabled **STL geometry import** for embedded boundaries representing complex reactor designs



Modeling provided critical outcomes leading to improved reactor design



- Model indicated a zone of poor mixing that we did not know about
- Revising bioreactor design led to improved production

Autonomously controlled bioreactors using AI predictions

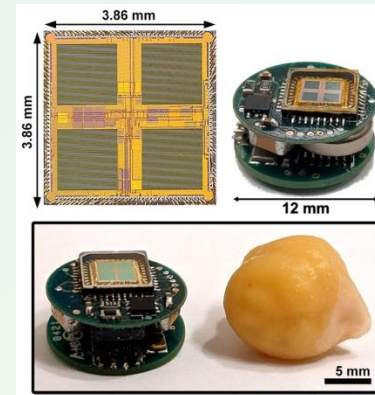
Create a **digital twin model** that considers all aspects of the bioreactor

- physical parameters
- the cellular state
- mass transport

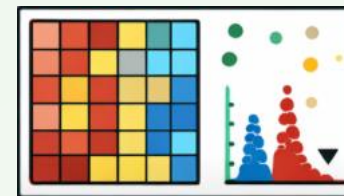


Fermentation Models

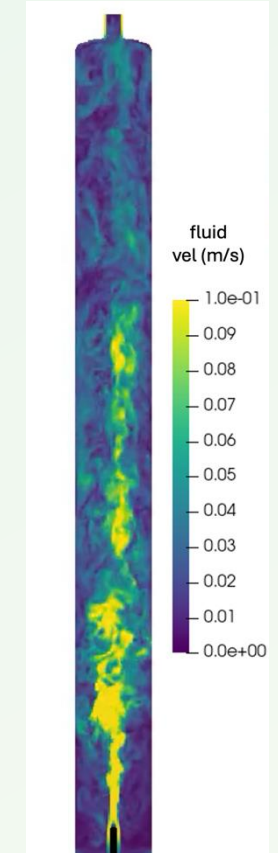
Small Wireless Sensors



AI Models



Transcriptomics



CFD Simulations

Capra Biosciences

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Bonnie Harper
Andrew Harper
Alexis Jerde



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